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Shear Field Aircraft Spars

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ABSTRACT

This paper is devoted to a discussion of some of the questions, factors, and problems that enter into the use of the so-called Wagner or shear web type of beam. Reasons for using this kind of spar in preference to others are given, along with an explanation of the method of stress analysis employed at the Douglas Aircraft Company. A few remarks on design practices are included.

COMPETITION for decreased structural weight and the consequent increased payload has resulted in very definite refinements and increases of structural efficiency. The first, and perhaps greatest, advance was made ten years ago by Wagner[1] in his report on the analysis of shear field beams in the waved state. Since that time, numerous theoretical studies and systematic tests have made it possible to approach the maximum strength-weight ratios that can be obtained with present-day materials.

REASONS FOR USE

A spar is entirely utilitarian by nature; *i.e.*, it is simply a part of the structure and has no direct bearing on comfort, pleasing appearance, aerodynamic performance, or mechanical operation. For this reason, a spar has only two conditions to fulfill; it must be easy and cheap to build and it must be efficient as a load carrying member. However, these two requirements are complicated. A consideration of cost of construction must take into account the overall cost of the airplane, while structural efficiency means more than just a high strength-weight ratio.

Presented at the West Coast Annual Meeting, I.Ae.S., Pasadena, California, June 17, 1939.

[1] Wagner, Herbert, *Flat Sheet Metal Girders with Very Thin Metal Web*, N.A.C.A. Technical Memoranda Nos. 605, 606, 1931.

COST

Experience has shown that the intrinsic cost of manufacturing a shear web spar is the lowest of all of the types investigated. The process of installing a flat sheet web between two spar caps and then riveting stiffeners to that web is simple and straightforward. Riveting accessibility at this stage of construction is good, complete tooling is easily accomplished, and the shop work can progress rapidly with a minimum of errors. Sheet and stiffener sizes can be stocked in large quantities because they can be used on many different models of airplanes with only a very small percentage of wasted material.

A great advantage from a cost point of view is the ease with which the Wagner spar can be adapted to quantity production methods. Pilot holes can be machine punched in the stiffeners before assembly, thereby speeding up the drilling of rivet holes. Large numbers of sheets for spar webs can be cut out at one time by the simple process of stacking them one on top of another. Automatic riveting machines can be used for the actual assembly of stiffeners and web to caps.

All of the above factors tend to lower the cost of a shear web spar, considered as an isolated unit.

Shear webs divide the internal volume of a wing or tail surface into several cells and care must be taken to avoid difficulty with inaccessible rivets when the outer skin is applied. This problem has been worked out by a variety of methods. Sometimes the skin is laid on at the leading edge first and is then progressively carried back toward the trailing edge or, as in the Douglas DC-3, the wing can be made of sub-assemblies. Only in extreme cases is it ever necessary to use stop nuts.

A similar question is the one of accessibility for inspection and maintenance after the airplane is built.

Such accessibility was furnished in the Douglas DC-4 by means of manholes and removable panels. It would have been necessary to furnish the same number of openings regardless of the type of spar used, so that the weight of these panels cannot be charged against the use of Wagner spars.

To offset the difficulty of applying the outer skin is the ease with which ribs may be attached to a webbed spar. At each rib station vertical stiffeners are placed on the spar and to these are riveted the chord and shear members of the rib. Gussets are ordinarily not needed at these points.

Low cost of assembly is also reflected in the ease of installation of the various accessory systems. Fuel lines, controls, and electrical conduits are readily supported at convenient points by simple brackets attached either to the vertical stiffeners or directly to the spar web. Wherever a hole must be cut through a spar, the web is customarily reinforced with a doubler around the hole if the hole is small, or with a doubler and frame if the hole is large.

Present-day trends toward integral fuel tanks in wings are forcing the use of shear webs in the spars immediately adjacent to the tanks. A single piece of sheet can extend from end to end of an integral tank and, in this manner, sealing difficulties can be minimized. Incidentally, a spar web that acts as a fuel tank wall must usually be several gages heavier than the stress analysis would otherwise indicate. This is to avoid deep wrinkles which tend to cause leaks at sealed joints or splices.

Related to the fuel tank problem is the question of flotation compartments. Here again, the wing or tail surface that contains Wagner type spars is at an advantage. Watertight cells can be sealed off with little or no expense by using flanged flat sheet ribs at certain points and sealing the edges with any of a number of commercially produced compounds.

The algebraic sum of all of these items makes the Wagner beam attractive from the standpoint of cost and convenience.

Structural Efficiency

A discussion of the structural efficiency of a spar takes in its all around ability to act as a load carrying member. Three important features must be considered; first is low vulnerability, second is low weight, and third is high rigidity.

By invulnerability is meant the ability to carry loads after damage, whether by accidental failure of one or more members of the structure or by bullets in wartime. This is largely a function of the degree of redundancy of the spar, since redundancy is defined as the possession of more degrees of support than are necessary for static stability. A statically determinate system cannot afford to lose any of its members: If it does it will collapse. A highly redundant structure, on the other hand will be weakened somewhat, but not entirely destroyed, if several members are removed.

Truss type spars are in most cases statically determinate, or at best have a very low degree of redundancy. If a single member is shot away, the beam is vitally injured. In contrast, the Wagner type of spar can afford to have half of its vertical stiffeners removed and have the web punched full of holes, and it will still retain a considerable part of its original strength.

The members of a truss spar, although farther apart, are much heavier and larger than the vertical stiffeners of a Wagner spar. Probability of being struck by bullets is therefore about equal in the two classes of beams, if the minor effect of a bullet hole through a spar web is neglected.

Low weight and high rigidity are the second and third items in structural efficiency. These two characteristics are closely related to each other and can very well be discussed together.

During the past few years it has been the custom at the Douglas Company to investigate several kinds of spars for each new class of airplane during the proposal and layout stages of design. Studies and tests have covered numerous types of trusses, such as Warren, Vierendeel, Howe, Pratt, and Diamond and various webbed types such as Vickers, box, and Wagner beams. In each case the beams are designed as light as possible to carry the loads as required by the stress analysis of the airplane. Weights, bending deflections, and shear deflections are then calculated or found by test and the results compared. The DC-4 can be taken as an example. For this airplane, three different spars were considered: diamond truss, Howe truss, and Wagner (Fig. 1). For reasons of efficiency of the wing corrugations in compression, the rib spacing was set at 20 inches so that the upright members of the

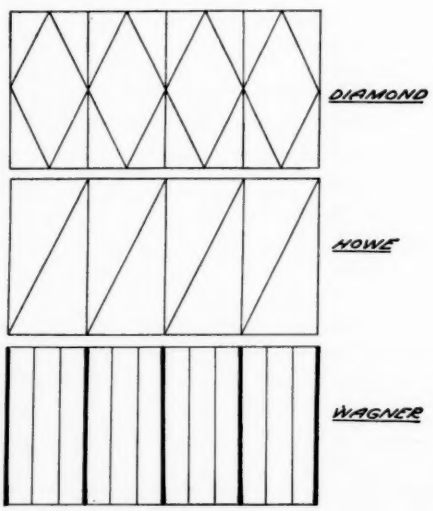

Fig. 1.

three spars were arranged to suit such a spacing. The spar height was about 40 inches.

Results can best be compared on a ratio basis. That is, the Wagner beam can be taken as a standard for weight and deflection and the other two spars can be compared with it. Table 1 gives these results.

TABLE 1

Spar	Wt.	Shear Defl.	Fig. of Merit
Diamond	1.36	1.46	.50
Howe Pratt	1.14	1.82	.48
Wagner	1.00	1.00	1.00

Since low weight and low deflection are desirable, a good figure of merit would be the reciprocal of the product of the weight and shear deflection ratios. This figure of merit for each of the three sample spars is given in the last column of Table 1.

There is nothing new or startling in this superiority of the shear web beam. Similar figures have been obtained for various sizes of Douglas ships from the 66,500 pound DC-4 down to the three-place TBD.

Past investigations have indicated that for deep sections with very light shear loads, a truss arrangement can weigh less than a stiffened shear web. For this reason, the typical lightly loaded ribs in several Douglas wings are truss structures. Ribs with heavy loads, however, are always of the shear web type for exactly the same reasons that govern the choice of spars.

Shear rigidity of the wing and tail beams is important in two ways. The first is to be found in the torsional rigidity of the whole cellule. It is more or less generally agreed that the prevention of the torsional-flexural variety of flutter is of major importance in the design of high performance airplanes. High torsional stiffness is usually an aid in raising the critical velocity for this type of wing flutter.

The other way in which shear rigidity of spars is important has to do with nose skin shear. A spar with large shear deflections permits the formation of deep wrinkles in the nose covering. Owing to the sharp nose curvature, such wrinkles tend to be permanent and do not disappear when the load is removed.

All of the above discussion covers the chief factors that have determined the selection of Wagner spars for wing and tail surface construction. Other features, such as corrosion, ease of repair, fatigue properties, and so forth, are about equal between different kinds of beams and have, therefore, had little influence in such a choice.

STRESS ANALYSIS

The basis of the Douglas method of stress analysis of stiffened shear webs is largely a matter of application of test results. Tests have been carried out systematically with this in mind so that curves could be developed for rapid design and analysis.

First let it be assumed that the applied shear load on a given spar station has been calculated. Such a load is the resultant of vertical shear and torsional stresses and has been corrected for the vertical components of the end loads in the spar caps. Owing to the direction of wing taper, the spar-cap end loads tend to react against a sizeable part of the vertical shear load.

Second, let it be assumed that the rib spacing has previously been determined. The stiffener spacing will be some simple fraction of the distance between ribs and, from past experience, will be selected so as to lie between 6 and 9 inches.

Division of the resultant shear load by the spar web height gives a running shear load, which in turn determines the gage of the web. Fig. 2 shows a curve of allowable running shear load against sheet thickness for the most commonly used material, 24STAL. The lines

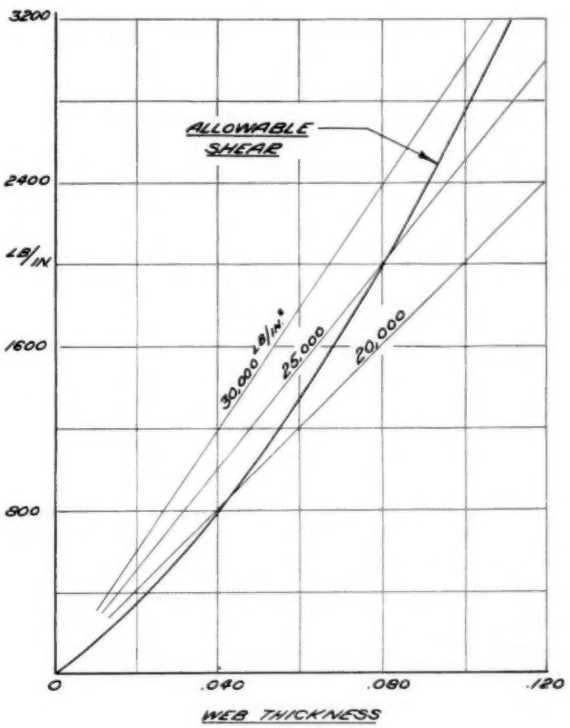

FIG. 2.

of unit stress indicate an increase of allowable stress with sheet thickness. Thus, an .040 web can carry 20,000 lbs. per sq.in. while a web .080 thick can carry 25,000 lbs. per sq.in. Test data have not been carried beyond .091 thickness. However, it seems probable that the permissible stress would continue to increase to a value of 30,000 lbs. per sq.in. for $^1/_8$ in. 24STAL plate. Beyond that point results would be of academic interest only, as far as aircraft are concerned.

Fig. 2 is based upon a ratio of stiffener weight to web weight of .5, *i.e.*, the cross-section area of a stiffener is taken to be one-half the thickness of the web multiplied by the stiffener spacing. Since the discussion began with an assumed spacing of stiffeners, and since sheets and extrusions are purchased in standard sizes, it is obvious that this ratio can seldom be fulfilled in practice. Fig. 3 has been developed to give a correction to Fig. 2 for other ratios.

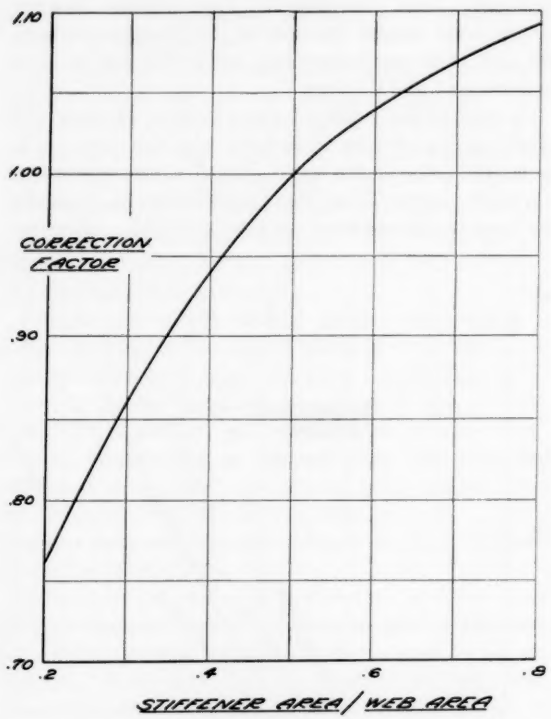

FIG. 3.

Fig. 3 gives a factor to be multiplied by the allowable running shear load given in Fig. 2. This factor is plotted against the ratio of stiffener area to web cross-section area and has the value 1.0 for a ratio of .5. The curve shows that an increase of stiffener size causes an increase of allowable shear stress. This has two very convenient features. First, it is possible to vary the strength of a given sheet within limits by simply adjusting stiffener sizes and thereby giving a continuous variation of spar strength along the span. Second, a replot of Fig. 3 shows the optimum stiffener-web ratio to use for the lightest possible weight of spar. Fig. 4 gives this replot. The correction factor of Fig. 3 divided by combined stiffener and web area is shown, plotted against the stiffener-web ratio. The results are encouraging. A maximum strength-weight ratio occurs in the neighborhood of a stiffener-web ratio of .4.

However, the curve has a very flat top, so that an extremely wide range of stiffener sizes can be used without appreciable loss of efficiency. It is this fact which makes the Wagner beam practical for use with standard pre-stocked stiffener sections as mentioned above under "costs."

A method of selecting web gages and stiffener sizes is now apparent. One uses the loads midway along the length of a given piece of sheet and the values of Fig. 2 to find the sheet thickness. Fig. 3 is then used to select stiffeners for the lowest weight that will carry the load at any given point. The result is a spar of peak structural efficiency.

Attachment of the spar web to the spar caps is based entirely upon the running shear load. Tests show that wrinkles and induced tension loads have little or no effect on the rivets. It is thus only necessary to make the shear strength per inch of rivets equal to or greater than the running shear load in the web. Usually double row riveting is employed.

A detailed discussion of spar caps is not within the scope of this paper. They are usually 24ST dural rolled or extruded shapes. The exact shape of cross-section depends upon a great number of practical influences, such as skin, corrugation and web attachments, integral tanks, method and amount of taper machining necessary, design of splices, etc. Often an assembled cap resembles either a large T section or a large bulb angle.

In the stress analysis, two types of secondary bending must be considered. First is the overall bending deflection of the wing, which almost always has a negligible influence on the spar cap. Second is the effect

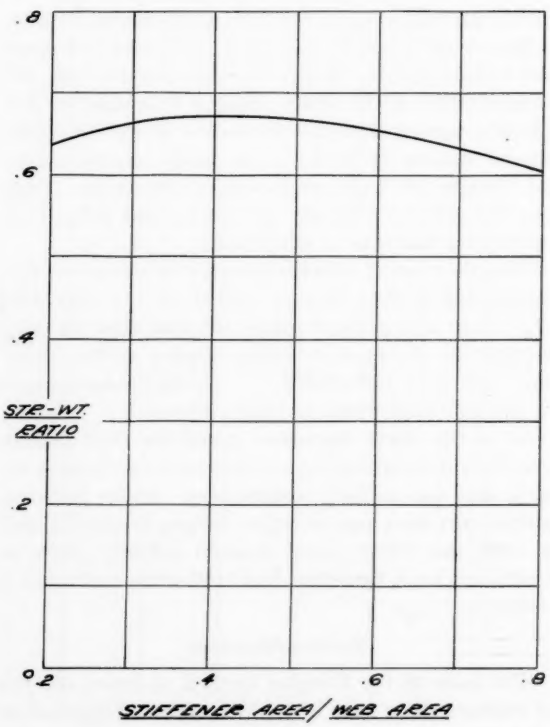

FIG. 4.

of the tension field in the web as a continuous side load. This also has but a small effect as long as the stiffener spacing is not too great. For large stiffener spacing this type of secondary bending and deflection can seriously decrease the strengths of both the cap and the web. Allowable stresses for beam caps are determined by test and are in the neighborhood of 45,000 lbs. per sq.in. compression or 62,000 lbs. per sq.in. tension for 24ST material.

Riveting of stiffeners to webs and caps has also been investigated. It has been found that each stiffener should be fastened at the ends by at least two rivets with a combined shear strength great enough to exert 7500 lbs. per sq.in. end load in the stiffener. Rivets through the web are calculated by the formula $S = 30{,}000\ A/h$ where S is the running shear strength of rivets in pounds per inch, A is the area of cross-section of the stiffener, and h is the stiffener spacing. This formula is based upon a type of design in which stiffeners are placed on both sides of the web, but is also used for the case of stiffeners on one side only.

Notes on Design Practices

Every construction problem has several solutions and the method finally chosen depends upon men and equipment available, raw stock on hand, standard parts, delivery dates, etc.

Present practice at the Douglas Company calls for complete development of both the jig and the loft templates. These two separate controls, one analytical and the other graphical, must coordinate with each other on assembly. It is therefore necessary for the engineer, tool designer, and loftsman to cooperate in obtaining a clear and accurate set of basic dimensions for use in all three departments.

24ST material has been found to be as efficient a material for spar webs as 24SRT on a weight basis. The softer material should be used because of its lower cost and better workability.

The best all-around stiffener arrangement has been found to consist of two extruded bulb angles, one on each side of the web. In cases where the shear loads are low, bent-up sheet angles or a single bulb angle are sometimes used. Hat sections and T sections, unless demanded by other design features of the airplane, should not be used, because they require more rivets and are no stronger than bulb sections.

Webs can well be fastened to one side of a vertical leg on a T section spar cap. The practice of clamping the edge of the web between two cap angles is advantageous only in comparatively heavy spars with very high shear loads.

Stiffeners at rib stations in most cases must be heavier than the method of analysis previously described will demand since the ribs themselves are adding loads to the spar. Most of this weight can be saved by making the intermediate stiffeners light enough to give an average stiffener-web ratio of .4 to .6. In no case should any stiffener be less than .2 times the web thickness times the stiffener spacing.

Sudden large changes in web gage are to be avoided, and doublers should be added in the region of attachment of heavily loaded bulkheads. Quite often it is difficult to determine the manner in which shear will transfer from one part of the structure to another and it is well to avoid if possible abrupt changes in section.

Present-day practice sets the minimum gage limit at .020 for spar webs. This figure is not entirely arbitrary. One important factor that enters the picture is the difficulty of doing satisfactory riveting in thinner gages, both from the standpoint of damaging the sheet and from handling extremely small rivets. The weight penalty is growing smaller every day as sizes and speeds of airplanes go up.

Where the shear stresses are very low in a web of .020 material, flanged lightening holes are introduced, and these can, if necessary, grow in size toward the tip until they consume the spar web altogether. Flanged holes actually exert a stiffening effect, in addition to saving weight and furnishing accessibility, for lightly loaded spars.

Occasionally a large access hole must be put through a spar web. In this case the type of framework around the hole depends upon the loads involved. One of the most efficient has been developed in the form of a diamond truss, with the truss members made of extruded bulb angles fastened to the web surrounding the hole. Gussets are added at the four corners of the diamond.

Book Review

Complex Variable and Operational Calculus, by N. W. McLachlan; Cambridge University Press, London, 1939; 355 pages, $6.50.

Written primarily for the applied mathematician, this book aims to provide a modern treatment of the so-called operational method.

Part I, on "Theory of Complex Variable," is a concise and thorough treatment of the subject. Illustrative examples are worked out.

"Theory of Operational Calculus," taken up in Part II, is based on a particular case of the Mellin inversion theorem, a proof of which is given in an appendix.

Part III, on "Technical Applications," takes up a number of problems, among them a problem in airplane dynamics. A list of 81 examples to be worked out by the student is included.

Appendices prove a number of mathematical theorems used in the analyses. A list of 222 references to the literature is included.

The increasing popularity of operational methods for the solution of aeronautical problems indicates that the book will be of considerable value to theoretical aeronautical engineers.

Analysis of Best Rate of Climb and Ceiling as Affected by Ice Accretions

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ABSTRACT

The polarless performance analysis is extended for non-parabolic polars which are characteristic of airfoils with surface irregularities such as ice accretions. Oswald's airplane efficiency factor is interpreted in terms of "pseudo aspect ratio." The condition of maximum rate of climb is analytically defined and its iterative determination is demonstrated for the case of a given non-parabolic polar.

Impairments of best climb due to ice as experienced in flight can with reasonable accuracy be considered as a function of the "pseudo aspect ratio" only. This eliminates the reliance on questionable airspeed indication in ice for the analysis of flight experiences. The climb impairments due to (ice) protuberances at various locations along the wing chord are evaluated as an example of the application of this theory to the rational development of anti-icing means.

I. INTRODUCTION

THE ultimate goal of all efforts to prevent or remove ice accretions is certainly the preservation of adequate airplane performance and controllability rather than the prevention or removal of ice accretions indiscriminately. It is the purpose of this investigation to provide a theory by means of which performance impairments as experienced in flight under icing conditions and wind-tunnel tests may be interpreted to accomplish a rating of different forms of ice accretions and of different means of ice removal on the basis of their influence upon airplane performance.

The Significance of Best Rate of Climb as a Performance Criterion under Icing Conditions

It is generally agreed that the impairment of airplane performance due to ice accretions is caused by the distortion of the airflow around the airplane rather than by the weight increase as a result of ice accretions. In fact for modern airplanes with high wing loading and without external bracing, this weight increase can be entirely neglected. Instead it is reasonable to assume that the aerodynamic effects of ice accretion can be duplicated by roughness, protuberances, or surface irregularities similar to those produced by ice formations. References 2, 3, 4, 5, and 6 contain a great amount of information concerning the influence of surface irregularities on lift and drag.

In Fig. 1 several polar curves are shown which are typical for the seemingly inconsistent influences of different surface irregularities upon lift and drag of wings. Three statements, however, can be made on the basis of the polar curves: (1) The drag at cruising speeds (low lift coefficients) is not functionally related to the drag at climbing speeds except for certain types of ice formations. For instance, ice formations on the bottom surface of the wing affect the cruising speeds greatly and the best climb little, while ice accretions at the top surface affect the cruising speeds little and the climb performance materially. (2) Maximum rate of climb, ceiling, in brief the ability to fly at all, is affected most by those forms of surface irregularities which produce increases of C_D with C_L. (3) $C_{L_{max.}}$ is most affected by surface irregularities which produce increases of C_D with C_L, *i.e.*, those ice forms which impair climb and ceiling most, also increase the landing speed most severely. Consequently, the means which may be provided on wings to preserve climbing ability can simultaneously be expected to restore slow landing speeds.

It is easily seen that impaired cruising performance due to ice accretions does not necessarily affect safety; neither do those impaired cruising speeds seriously affect scheduled operation on those rare occasions when ice is encountered; hence the attention is focused upon the condition of best rate of climb and it may be expected that any steps to restore climbing ability in icing conditions will also be a remedy for all of the other flight conditions at slow speeds, namely, take-off, landing, and maximum range.

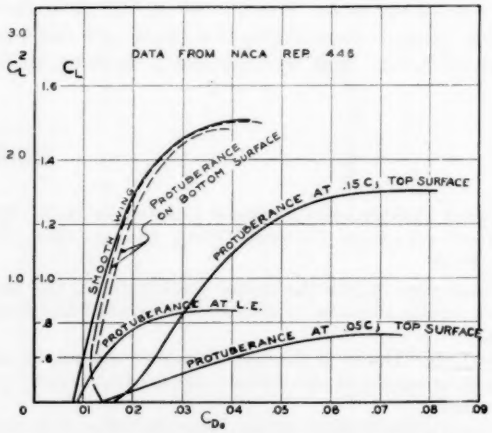

FIG. 1. Polars as affected by protuberances (ice).

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Notations

Standard N.A.C.A. notations (Ref. 1) were employed in this paper with the following exceptions or additions.

P_A = Thrust horsepower available
= Ab.hp.η
(A = Horsepower conversion factor)
P_R = Thrust horsepower required for level, unaccelerated flight
a = "Pseudo aspect ratio" = $(1/\pi)dC_L^2/dC_{D_0}$
C_{D_0} = C_D for infinite aspect ratio, A
τ_V = $\sqrt[4]{K}$ = "Speed Modulator"
τ_D = $(K+1)/\sqrt{K}$ = "Drag Modulator"
τ_P = $(K+1)/\sqrt[4]{K}$ = "Power Modulator"
V_b = V/τ_V = "Basic Speed"
D_b = D/τ_D = "Basic Drag"
P_b = P_R/τ_P = "Basic Power Required"
$()_C$ Denotes the condition for maximum rate of climb.

II. Pseudo Aspect Ratio

The fact that the polar curves for wings with surface irregularities (Fig. 1) are not even approximately parabolas, *i.e.*, straight lines when plotted on a C_L^2 scale seems to preclude their analytical representation as used in the polarless methods of performance estimation. However, if the condition for the maximum rate of climb is considered exclusively, only a small portion of the polar curve is of interest and this small piece may well be replaced by a parabola (compare Fig. 2). This parabola (appearing as a straight line

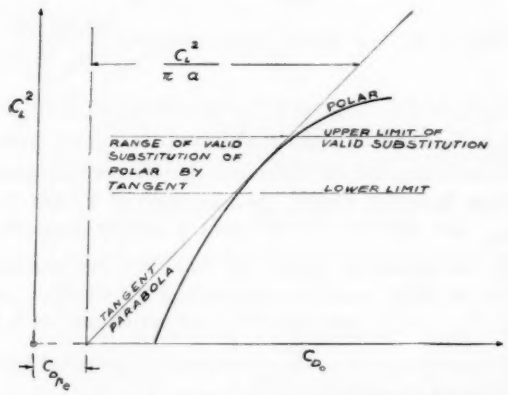

Fig. 2. Substitution of a non-parabolic polar by a tangent parabola.

in the C_L^2 *vs.* C_D diagram) then represents the polar curve as far as it is of interest for the condition of the best rate of climb. This parabola obviously resembles a polar curve consisting of a constant effective parasite drag coefficient $C_{D_{p_e}}$ and an induced drag coefficient $C_L^2/\pi A$. Since, however, the drag coefficients in Fig. 2 are corrected for infinite aspect ratio, there is obviously no induced phenomenon responsible for the slope of the tangent, dC_L^2/dC_{D_0}. For reasons stated in reference 7 this dC_L^2/dC_{D_0} may be explained by a decrease of lift due to boundary layer thickening only. The tangent to the polar in Fig. 2 may therefore be represented by the equation, $C_{D_0} = C_{D_{p_e}} + C_L^2/\pi a$.

Where a shall be called pseudo aspect ratio and $C_L^2/\pi a$ designates what may be termed pseudo induced drag. These terms "pseudo" aspect ratio and "pseudo" induced drag are chosen to characterize the inclination of the straight line polar curve (Fig. 2) as being equivalent to induced drag although this inclination is undoubtedly a viscosity or boundary layer phenomenon which is in no way physically related to induced phenomena; hence any polar curve for a finite geometric aspect ratio A takes the form

$$C_D = C_{D_{p_e}} + \frac{C_L^2}{\pi A} + \frac{C_L^2}{\pi a} \tag{1}$$

The range of validity of a formula of this type depends on the range within which any actual polar curve can be represented by a straight line when plotted against C_L^2. Eq. (1) permits the correction of any flight or wind-tunnel tests for geometric aspect ratio provided similarity is otherwise retained.

As long as the aspect ratio is not changed—that is if one type of airplane is considered in various icing conditions—Oswald's formula[1]

$$C_D = C_{D_{p_e}} + C_L^2/\pi eA \tag{2}$$

may be applied. Where $C_{D_{p_e}}$ is identical with $C_{D_{p_e}}$ in Eq. (1),

$$\frac{C_L^2}{\pi eA} = \frac{C_L^2}{\pi A} + \frac{C_L^2}{\pi a} \tag{3}$$

and e is Oswald's well known "airplane efficiency factor."

The pseudo induced drag is treated as a genuine induced drag in Eq. (2), since for $A = \infty$ the term $C_L^2/\pi eA$ disappears, which actually does not hold for the resistances due to viscosity. To avoid sizable* errors, e must be corrected for changes of A. From Eq. (3) the relation between e, A, and a is found to be

$$e = 1/(1 + A/a) \tag{4}$$

The correction of e according to Eq. (4) makes it possible to retain the convenient simplicity of Oswald's formula and takes into consideration that the pseudo aspect ratio, a, and not the airplane efficiency factor, e, is a constant.

III. The Condition of Best Rate of Climb

Thus far it was assumed that the range of best rate of climb in the polar diagram be known. Until this

* Without proper consideration of e as a variable, errors of the order of 400 feet per minute rate of climb can be introduced, if flight experiences with a pursuit plane ($A = 5$) are applied to a transport airplane ($A = 9$).

location of the condition of best rate of climb is established, there is obviously the choice of an infinite number of parabolas tangent to the non-parabolic polar representing a certain icing condition. Drawing various tangents to a curved polar diagram shows a (or e) and $C_{D_{p_e}}$ to be a function of the lift cofficient at the point of tangency. Hence the problem of analytically expressing the parabola (straight line in C_L^2 vs. C_D diagram) approximating the non-parabolic icing polar is to find C_{L_C}, a_C, and $C_{D_{p_{e_C}}}$, where subscript C denotes the condition for maximum rate of climb, $(dh/dt)_{max.}$. This is done as follows:

By definition $$K \equiv C_{D_{p_e}}/C_{D_{i_e}}$$

where $C_{D_{i_e}} = C_L^2/\pi eA$ = Effective induced drag coefficient.

Hence, $$K = C_{D_{p_e}}\pi eb^2/C_L^2 S$$

and

$$C_L = \frac{b}{S}\sqrt{\frac{\pi ef}{K}} \tag{5}$$

where $$f = C_{D_{p_e}} S$$

Assuming lift = weight

$$L = W = C_L S(\rho/2)V^2$$

Introducing Eq. (5) and solving for V

$$V = \sqrt[4]{K}\sqrt[4]{4W^2/\rho^2\pi f e b^2} \tag{6}$$

which may be written

$$V = \tau_V V_b \tag{7}$$

Where $\tau_V = \sqrt[4]{K}$ = "Speed Modulator" (8)

and $$V_b = \sqrt[4]{\frac{4W^2}{\rho^2\pi f e b^2}} = \text{"Basic Speed"} \tag{9}$$

The total drag, D, is $D = (K+1)D_{i_e}$, since $K = C_{D_{p_e}}/C_{D_{i_e}} = D_{p_e}/D_{i_e}$. The effective induced drag $D_{i_e} = 2W^2/\pi eb^2\rho V^2$ in connection with Eq. (6) gives

$$D = \frac{K+1}{\sqrt{K}}\sqrt{\frac{fW^2}{\pi eb^2}} \tag{10}$$

or

$$D = \tau_D D_b \tag{11}$$

where $\tau_D = (K+1)/\sqrt{K}$ = "Drag Modulator" (12)

and $$D_b = \sqrt{\frac{fW^2}{\pi eb^2}} = \text{"Basic Drag"} \tag{13}$$

The thrust horsepower required $P_R = DV$ is found by multiplying Eq. (10) by Eq. (6),

$$P_R = \frac{K+1}{\sqrt[4]{K}}\sqrt[4]{\frac{4fW^6}{\pi^3\rho^2 e^3 b^6}} \tag{14}$$

or $$P_R = \tau_P P_b \tag{15}$$

where $\tau_P = (K+1)/\sqrt[4]{K}$ = "Power Modulator" (16)

and $P_b = \sqrt[4]{\frac{4fW^6}{\pi^3\rho^2 e^3 b^6}}$ = "Basic Power Required" (17)

The sinking speed $w_S = P_R/W$

or $$w_S = \tau_P P_b/W \tag{18}$$

in unaccelerated flight $P_A = W\,dh/dt + P_R$ (19)

where P_A = b.hp.ηA = Thrust Horsepower Available, A = Horsepower Conversion Factor, and dh/dt = Rate of Climb. Solving for dh/dt, differentiating with respect to V, and equating to zero gives the condition for maximum rate of climb.

$$\frac{d(dh/dt)}{dV} = \frac{d(P_A/W)}{dV} - \frac{dw_S}{dV} = 0 \tag{20}$$

or

$$\frac{A\text{b.hp.}}{W}\left(\frac{d\eta}{dV}\right)_C = \left(\frac{d\tau_P}{d\tau_V}\right)_C \frac{P_b}{WV_b} = \frac{3K_C - 1}{\sqrt{K_C}}\frac{D_{b_C}}{W} \tag{21}$$

These equations yield K_C, the ratio of parasite over induced drag at best rate of climb, as a function of power, propeller, and airplane characteristics:

$$\frac{3K_C - 1}{\sqrt{K_C}} = \frac{A\text{b.hp.}}{D_{b_C}}\left(\frac{d\eta}{dV}\right)_C \tag{22}$$

in Fig. 3, K_C, τ_{V_C}, and τ_{P_C} are plotted *vs.* $\dfrac{A\text{b.hp.}}{D_{b_C}}\left(\dfrac{d\eta}{dV}\right)_C$.

Fig. 3, or Eq. 22 permit the determination of C_{L_C}, V_C, w_{S_C}, P_{R_C}, and D_C with any degree of accuracy without the tedious graphical differentiation formerly employed. Since, however, $(d\eta/dV)$ is a function of V, and a and $C_{D_{p_e}}$ are different for different parabolic tangents to the non-parabolic polar, the condition for maximum rate of climb must be approached by iteration until a_C, $C_{D_{p_{e_C}}}$, C_{L_C}, and $(d\eta/dV)_C$ are consistant with Eq. 22 and the polar. This iteration is illustrated by the following example.

Given: the polar as per Fig. 4, W, S, b, b.hp., and the propeller characteristics. The problem is to find the parabola $C_{D_{p_{e_C}}} + \dfrac{C^2_{L_C}}{\pi A} + \dfrac{C^2_{L_C}}{\pi a_C}$ representing the polar in the range of maximum rate of climb.

In order to approximate the tangent T_1 which is likely to represent the polar in the neighborhood of C_{L_C} consider: $d\eta/dV$ is positive at climbing speeds. Hence $K_C \geqq .333$ (Fig. 3) and consequently $C_{D_C} =$

$C_{D_{p_{e_C}}} + C_{D_{p_{e_C}}}/K_C \leqq 4C_{D_{p_{e_C}}}$ or $C_{D_{p_{e_C}}} \geqq {}^1/_4 C_{D_C}$.

Therefore, a tangent T_1 determined by $C_D = 4C_{D_{p_e}}$ represents an upper limit and is likely to cover the best climb condition for moderate values of $\frac{A\text{b.hp.}}{D_b}\left(\frac{d\eta}{dV}\right)$. $C_{D_{p_e}}$ and a for T_1 are easily obtained. The range of lift coefficients, within which T_1 represents the actual polar, permits the determination of an average value of $(d\eta/dV)_1$ for the corresponding speeds. Hence $\frac{A\text{b.hp.}}{D_{b_1}}\left(\frac{d\eta}{dV}\right)_1$ may be calculated and K_1 be obtained from Fig. 3. If for $C_D = C_{D_{p_{e_1}}}(1 + 1/K_1)$ the tangent T_1 is a satisfactory representation of the polar, the problem is solved, since then $C_{D_{p_{e_1}}} = C_{D_{p_{e_C}}}$; $a_1 = a_C$. If, however, the polar is strongly curved and/or $\left(\frac{d\eta}{dV}\right)\frac{A\text{b.hp.}}{D_b}$ is large, a second tangent T_2 must be assumed because $C_D = C_{D_{p_{e_1}}}(1 + 1/K_1)$ and T_1 will not intersect close to the actual polar under such circumstances. For the choice of T_2 consider: K_1 obviously calls for $C_{D_{p_{e_C}}} > C_{D_{p_{e_1}}}$; $a_C > a_1$; (or $e_C > e_1$); $C_{L_C} < C_{L_1}$ $\therefore$ $V_C > V_1$ and $\left(\frac{d\eta}{dV}\right)_C < \left(\frac{d\eta}{dV}\right)_1$ (since $\frac{d^2\eta}{dV^2} < 0$ at climbing speeds). It follows that $\frac{A\text{b.hp.}}{D_{b_C}} \times \left(\frac{d\eta}{dV}\right)_C < \frac{A\text{b.hp.}}{D_{b_1}}\left(\frac{d\eta}{dV}\right)_1$. Hence (Fig. 3) $K_C < K_1$ and $C_{D_C} < C_{D_{p_{e_C}}}(1 + 1/K_1)$. Therefore, a tangent T_2 which represents the polar with $C_D = C_{D_{p_{e_1}}}(1 + 1/K_1)$ as upper limit of valid substitution is likely to satisfy the condition of best climb. This may be checked by determining C_{L_C}, V_C, $(d\eta/dV)_C$, $\frac{A\text{b.hp.}}{D_{b_C}}\left(\frac{d\eta}{dV}\right)_C$, K_C (from Fig. 3), and $C_{D_C} = C_{D_{p_{e_C}}}(1 + 1/K_C)$. If C_{L_C} and C_{D_C} check the polar, the condition of maximum rate of climb is accurately met.

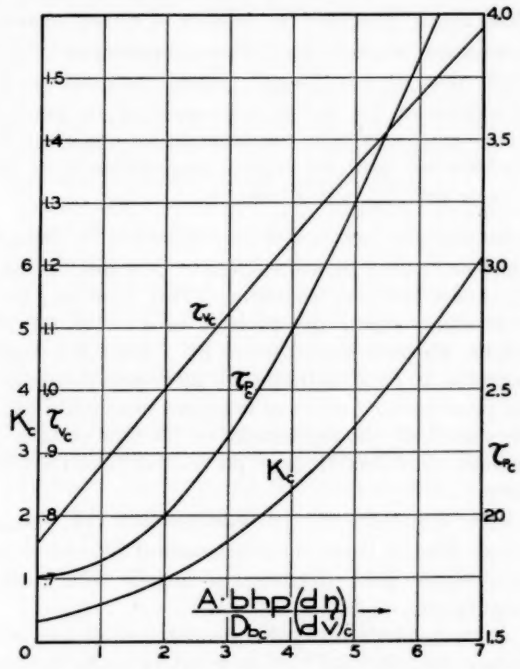

FIG. 3. Relationship of the parameters K_C, τ_{V_C}, τ_{P_C}.

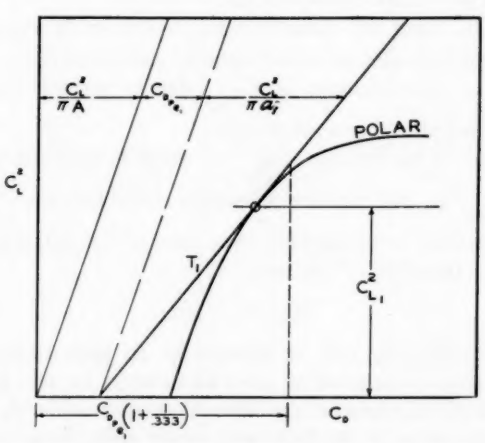

FIG. 4. Determination of a_C and $C_{D_{p_{e_C}}}$.

It is to be noted that the determination of the condition of best rate of climb as treated so far is not restricted to icing problems. Even for airplanes with smooth surfaces the polar curve is not a straight line when plotted *vs.* C_L^2. The failure of the polarless methods of performance estimation to consider this non-parabolic property of the polar diagram is its major weakness. The above analysis gives due consideration to the variability of $C_{D_{p_e}}$ and a without sacrificing the labor saving, accurate, and versatile analytical representation.

The introduction of the ratio K as performance parameter permits a convenient orientation in the polar diagram for the accurate determination of a and $C_{D_{p_e}}$ for any flight condition under consideration.

IV. Maximum Rate of Climb at Altitude

Eqs. (19), (14), and (15) give

$$\left(\frac{dh}{dt}\right)_{max.} \equiv C = \frac{P_{A_C}}{W} - \tau_{P_C}\sqrt[4]{\frac{4fW^2}{\pi^3\rho^2e^3b^6}} \tag{23}$$

Multiplying by $\sigma^{\frac{1}{2}} = (\rho/\rho_0)^{\frac{1}{2}}$,

$$C\sigma^{\frac{1}{2}} = \frac{P_{A_C}}{W}\sigma^{\frac{1}{2}} - \tau_{P_C}\sqrt[4]{\frac{4fW^2}{\pi^3\rho_0^2e^3b^6}} \tag{24}$$

where

$$\tau_{P_C} \sqrt[4]{4fW^2/\pi^3\rho_0^2e^3b^6} = w_{S_C}\sigma^{\frac{1}{4}}$$

is independent of density or altitude under the following assumptions:

(a) W does not change with altitude. Actually it does change slightly due to fuel consumption.

(b) Changes of e and f due to variations of Reynolds Number and slipstream interference with altitude are negligible.

(c) Variations of dP_A/dV with altitude are moderate such as to produce only negligible changes of τ_{P_C} with altitude (Fig. 3), which is a reasonable approximation for constant speed propellers. If the additional assumption holds, that ice accretions do not appreciably affect the thrust horsepower available at any altitude, the impairments of best climb at any altitude are explained by changes of $w_{S_C}\sigma^{\frac{1}{4}}$ only:

$$\Delta C\sigma^{\frac{1}{4}} = -\Delta w_{S_C}\sigma^{\frac{1}{4}} \tag{25}$$

Where

$$\Delta C\sigma^{\frac{1}{4}} = (C\sigma^{\frac{1}{4}})_{(without\ ice)} - (C\sigma^{\frac{1}{4}})_{(with\ ice)}$$

and

$$\Delta w_{S_C}\sigma^{\frac{1}{4}} = (w_{S_C}\sigma^{\frac{1}{4}})_{(without\ ice)} - (w_{S_C}\sigma^{\frac{1}{4}})_{(with\ ice)}$$

On the basis of Eq. (25) and the assumption that $w_{S_C}\sigma^{\frac{1}{4}}$ and $\Delta w_{S_C}\sigma^{\frac{1}{4}}$ are independent of altitude, the best rates of climb for any altitude and ceiling corresponding to a given $\Delta C\sigma^{\frac{1}{4}}$ are extrapolated most conveniently as follows: Since $C = f(h)$ for a given airplane and weight in absence of ice accretions is known, $C\sigma^{\frac{1}{4}} = \varphi(h)$ may be calculated and plotted (Fig. 5). Let this airplane at this weight encounter ice at the altitude h_{ice} and its best rate of climb is C_{ice}. Then $C_{ice}\sigma^{\frac{1}{4}}{}_{h_{ice}}$ may be plotted in Fig. 5 and $C_{ice}\sigma^{\frac{1}{4}} = \psi(h)$ can be extrapolated parallel to $C\sigma^{\frac{1}{4}} = \varphi(h)$ (dashed line). The ceiling corresponding to this icing condition is found at the intersection of $C_{ice}\sigma^{\frac{1}{4}} = \psi(h)$ and $C\sigma^{\frac{1}{4}} = 0$. It will be noted that for this extrapolation of the ceiling corresponding to a certain icing condition, no insight is required into the factors which account for $\Delta w_{S_C}\sigma^{\frac{1}{4}}$.

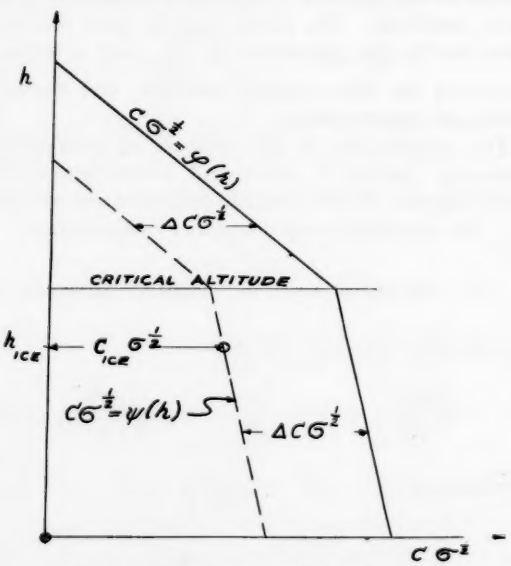

FIG. 5. Extrapolation of climb impairments.

V. Analysis of Climb Impairments Due to Ice, as Experienced in Flight

In sections II and III a method is developed by means of which the best climb in icing conditions can be determined with any degree of accuracy if the polar is known.

In section IV, flight experiences in ice are shown to yield $\Delta w_{S_C}\sigma^{\frac{1}{4}}$ provided the validity of certain assumptions stated above holds. These impairments of best climb due to ice, $\Delta w_{S_C}\sigma^{\frac{1}{4}}$, though permitting the estimation of the ceiling corresponding to the particular icing condition encountered, are not generally interpretable until the relative magnitudes of e_C and f_C or a_C and $C_{D_{P_{e_C}}}$ are known.

An indication of a_C and f_C, responsible for $\Delta w_{S_C}\sigma^{\frac{1}{4}}$, could be derived from the speed at best rate of climb, V_C, under the icing condition. This approach, however, seems highly questionable in view of the unreliable airspeed indication in ice. Even the highly perfected ice removal from pitot tubes does not remedy the pitot position errors of unknown magnitude which are caused by the disturbance of the flow pattern on account of ice accretions on parts other than the pitot tube.

The approach to the interpretation of $\Delta w_{S_C}\sigma^{\frac{1}{4}}$ chosen here is based upon generalized characteristics of available polar diagrams of airfoils with surface irregularities.

A great number of polar diagrams of airfoils with surface irregularities[2,3,4,5,6] were subjected to analyses as outlined in section III.

These evaluations indicate:

(1) That the changes of $\dot{w}_{S_C}$ due to surface irregularities are almost entirely due to variations of a_C.

(2) The changes of $C_{D_{P_{e_C}}}$ due to surface irregularities are in general $\leqq .005$.

(3) The average $C_{D_{P_{e_C}}}$ is roughly identical with $C_{D_{P_{e_C}}}$ in the absence of surface irregularities. It is therefore, recommended that $\Delta w_{S_C}\sigma^{\frac{1}{4}}$ be interpreted as a function of Δa_C only.

$$\Delta w_{S_C}\sigma^{\frac{1}{4}} = \varphi(a_C) \tag{26}$$

Although Eq. (26) is admittedly an approximation, its scope is believed to cover all forms of ice accretions and its inaccuracies are believed small considering the inaccuracies of the flight test results under icing conditions. In view of (a) the limited accuracy required

for the estimation of performance in ice, and (b) the random character of $\Delta C_{D_{p_{eC}}}$ due to ice, the statistical average of flight results is likely to be more accurate if the analysis is carried out in terms of a_C.

VI. Impairment of Best Climb Due to (Ice) Protuberances

The following example demonstrates the use of the theory. Reference 3 (Figs. 2 to 10) shows the polars of airfoils with fullspan protuberances at various locations along the section contour. The polars for protuberances of .005c in height were analyzed as per section III, assuming $A = 8$, $C_{D_{p_{eC}}} = .018$ for the total airplane without protuberances, and $\frac{Ab.hp.}{D_{bC}}\left(\frac{d\eta}{dV}\right)_C = 2$. The values of a_C^{-1} and $C_{D_{p_{eC}}}$ thus found are plotted in Fig. 6, *vs.* the bottom and top contour stations of the airfoil as abscissa. Over the same abscissa the corresponding values of w_{S_C} are plotted assuming $w_{S_C} = 100$ in the absence of any protuberance.

The data given in Fig. 6 are interpreted as follows: A protuberance or ice formation at the 5 percent station on the top surface of the wing causes $1/a_C$ to increase to 3.6 times its value for the same protuberance at the leading edge. The protuberance at .05c about doubles the sinking speed whereas the same ice ridge at the leading edge increases the sinking speed by about 20 percent only.

The inflatable anti-icing shoes in general use in this country happen to cover not more than the leading 5 percent of the wing and do not, therefore, protect against the most detrimental ice formations in the neighborhood of the 5 percent station. The data of reference 3 obviously call for an extension of the coverage of the anti-icing means over at least 20 percent of the upper wing surface. It is most probable that for all airplanes with reasonable climbing ability in the absence of ice, increases of the sinking speed at best climb condition can be tolerated if they do not exceed roughly 20 percent. This would mean that to safeguard such a minimum performance still only about 20 to 30 percent of the wing surface need be provided with anti-icing means.

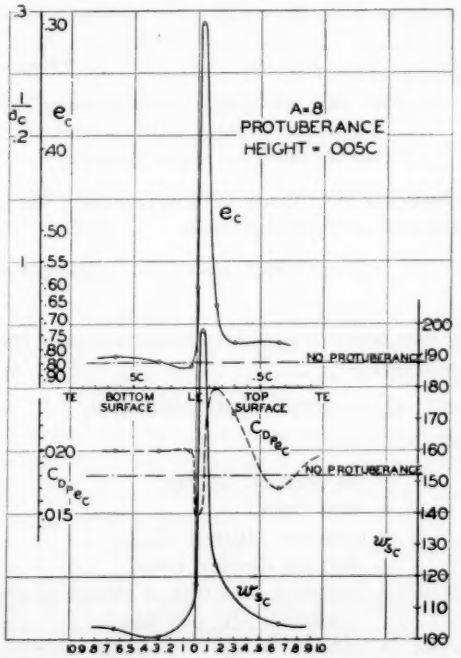

FIG. 6. The effect of various chordwise protuberance locations upon a_C^{-1}, $C_{D_{p_{eC}}}$, and w_{S_C}.

VII. Conclusions

By means of the above theory it is possible to establish the relationship between size, shape, and location of ice accretion and a generally applicable aerodynamic parameter, a_C (and perhaps $C_{D_{p_{eC}}}$) depending upon the flight or wind-tunnel test results available for analysis. Once a_C (and possibly $C_{D_{p_{eC}}}$) is obtained for the most important ice formations, it will be possible to predict whether or not an airplane will be able to maintain flight above a certain altitude under certain anticipated icing conditions. Furthermore, the merits of various anti-icing means can be rated in terms of their effectiveness in preserving climbing ability and ceiling, thus permitting a more rational development of such anti-icing equipment.

No consideration has been given to propeller icing. Very little is known about the effect of surface irregularities upon propeller efficiency and about the shape of ice accretions on propellers. Hence, analyses of climb impairments with ice on the propeller have to be taken with reservations. However, the ice removal from propeller blades is expected to be effectively accomplished in the near future. Furthermore, the influence of ice accretions on the blade shanks during climb is not believed to be great compared to the effect of ice accretions on wings, provided ice is not forming on blade sections producing the major thrust.

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The Reduction of Flight Test Climb Data to Standard Air Conditions

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SUMMARY

General equations for the reduction of flight test climb data to standard air conditions are given, indicating how the airplane and engine characteristics affect the necessary rate of climb corrections. Charts are given to provide an aid in the reduction of climb data of airplanes having modern engine installations.

The method of climb reduction presented is then expressed in terms of the "equivalent climb altitude," which has had wide use in the past. The author feels that this correlation shows the limitation of each method, and when one or the other is best suited. The equivalent climb altitude constant K is shown to depend mainly upon Oswald's airplane parameter Λ which enables K to be readily selected for most any type of airplane. While $K \cong 0.37$ for modern bimotor airplanes in two engine climb, it may increase to $K \cong 0.50$ for the same airplane in single engine flight.

INTRODUCTION

THE necessity for reducing climb observations to standard conditions was realized as far back as about 1915, at which time it was observed that the airplane performance and engine performance varied in different ways with changes in the atmospheric pressure and temperature. In 1926, Diehl[1] developed a method of correcting airplane climbs which has had wide use in this country. In his report a very complete résumé of previous work done on the correction of airplane climbs is given. A somewhat similar method had been developed in England, being referred to as the "half and half" method.[2] Recently, the U. S. Army has adopted a method which is rational and somewhat similar to the method and charts presented in this paper. The present paper explains and shows the relationship between existing methods of correcting rates of climb and shows how the various airplane characteristics may affect these corrections.

The problem of correcting climb data resolves itself into, first, determining the true rate of climb of the airplane with reference to the density altitude, and second, correcting this climb for the excess or deficient engine power. The equivalent climb altitude method, as will be shown, shortcuts the above procedure; but in doing so introduces the aerodynamic characteristics of the airplane as another variable.

CALCULATION OF THE TRUE RATE OF CLIMB

The true rate of climb is not measured directly by observing the change of altitude readings on the altimeter, as this being a pressure instrument only pressures are observed; the readings being given in terms of standard pressure altitude. It will be shown further on that the observed change in the altimeter with time will give the true rate of climb only if standard air conditions exist. It does not matter whether an altimeter or barograph is used to record the pressure as long as the changes in pressure Δp for given time increments Δt are determined. It has been the author's experience that just as reliable data can be obtained from the modern sensitive altimeters as with recording barographs, and certainly with more convenience. As both the altimeter and recording barograph are in common use, equations will be presented which may be conveniently applied to either instrument.

Having observed a given pressure change Δp over a time interval Δt the true change in altitude $\Delta H'$ is given as,

$$\Delta H' = \Delta p/\delta_a$$

where

δ_a = specific weight of the air (lb. per cu.ft.)
Δp = change in air pressure (lb. per sq.ft.).

Small increments of pressure and time permit differential values to be used, giving

$$C_{h_i} = \Delta H'/\Delta t = dH'/dt = (1/\delta_a)dp/dt$$

where

C_{h_i} = true rate of climb corresponding to the particular density altitude (not corrected for the effects of engine power).

If a climb has been made using a recording barograph the true rate of climb is given as

$$C_{h_i} = [70.732/\sigma(0.07651)]dp'/dt = (924.5/\sigma)dp'/dt \quad (1)$$

In the case where a sensitive altimeter is used the true rate of climb is

$$C_{h_i} = (924.5/\sigma)(dp'/dh)(dh/dt) \quad (2)$$

where

p' = air pressure (in. Hg)
t = time (min.)
h = pressure altitude (ft.)
σ = altitude density ratio
dh/dt = observed time rate of change of pressure altitude (ft. per min.)
dp'/dh = rate of change of pressure with pressure altitude (in. Hg per ft.).

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The value of dp'/dh may be calculated from the standard atmosphere tables. It can be shown that for standard conditions,

$$(924.5/\sigma)dp'/dh = 1.00$$

which implies that the value of dh/dt, obtained using the altimeter under standard conditions, will be the true rate of climb. From Eqs. (1) and (2) it is seen that the true rate of climb is inversely proportional to the relative air density σ. For this reason it is proposed to introduce a factor, F, which is defined as the variation of the air density at a given pressure altitude from its standard value at this altitude, due to the variation of air temperature from the specified standard value. The relative standard air density ratio at altitude is

$$\sigma_s = (p_s/p_0)(T_0/T_s)$$

where the subscripts $()_0$ refer to standard conditions at sea level and the subscripts $()_s$ refer to standard conditions at altitude. The absolute air temperature is denoted by T.

At a given pressure altitude the actual relative air density may then be given as,

$$\sigma = \sigma_s F \tag{3}$$

where

$$F = (273 + t_s)/(273 + t_m)$$

t_m, t_s = measured and standard outside air temperature in degrees Centigrade.

Fig. 1 enables F to be readily found for observed values of pressure altitude h and outside air temperature t_m.

The resulting equation for the true rate of climb for barographs recording the pressure in inches of Hg then becomes

$$C_{h_t} = (924.5/\sigma_s F)dp/dt \tag{4}$$

When a sensitive altimeter is used the corresponding equation is

$$C_{h_t} = (1/F)dh/dt \tag{5}$$

Values of dp/dt and σ_s must be selected for different pressure altitudes and F calculated for the observed outside air temperature at the particular pressure altitude. The values of C_{h_t} calculated above, are the true rates of climb for the airplane at the air density calculated from the pressure altitude h and observed outside air temperature t_m, hence should be referred to the corresponding density altitude.

The density altitude is most easily found by determining an increment of altitude ΔH to be added to the pressure altitude to give the density altitude. This is a function of F and pressure altitude and is given by

$$\Delta H = \Delta\sigma dH/d\sigma_s = (1 - F)\sigma_s(dH/d\sigma_s) \tag{6}$$

Values of σ_s and $dH/d\sigma_s$ have been found from the standard atmosphere tables permitting the curves shown in Fig. 2 to be calculated. If the variation of engine power did not affect the rate of climb, the problem would now be solved, since the true rate of climb *vs.* altitude curve could be found by plotting several values of C_{h_t} against the density altitude calculated from the relation

$$\text{Density altitude} = H = h + \Delta H \tag{7}$$

Correction of Rate of Climb for Engine Power

In order to correct the true rates of climb as determined in the previous section for the effect of engine power it is necessary to first determine from power curves (or torque meter readings) the actual b.hp.$_m$ used during the rate of climb measurement. This must be subtracted from the b.hp.$_H$ that the engine is specified to develop for the corresponding density altitude giving an increment of power denoted as Δb.hp. It should be carefully noted that the specified b.hp.$_H$ must be that for the density altitude as the true rate of climb C_{h_t} is referred to this altitude. The correction to be added to the true measured rate of climb is then expressed as

$$\Delta C_h = 33{,}000\eta_c(\Delta\,\text{b.hp.})/W \tag{8}$$

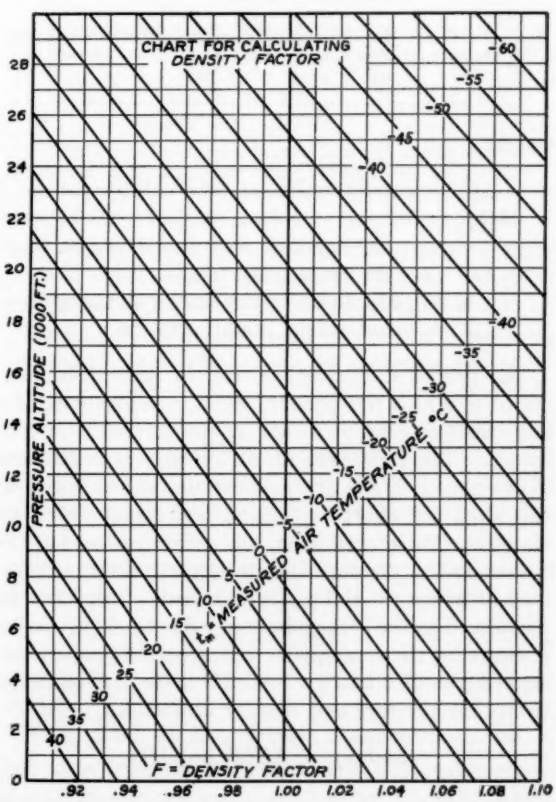

FIG. 1. Chart for obtaining F for measured values of h and t_m.

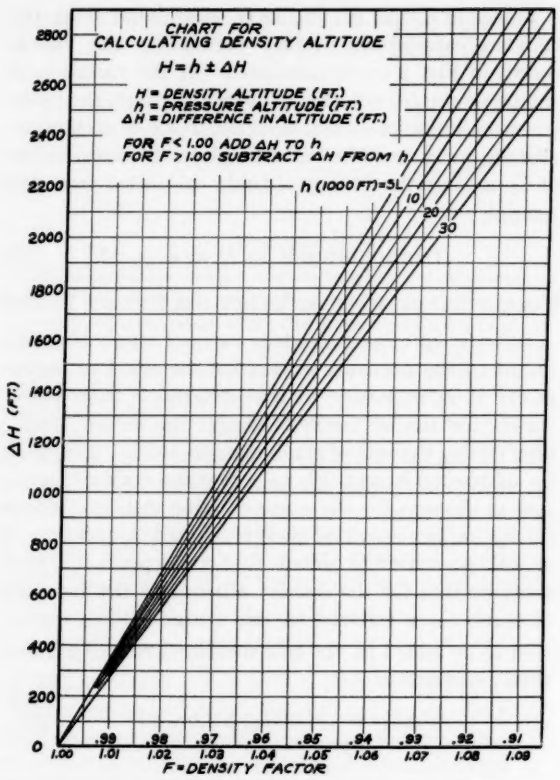

FIG. 2. Chart for obtaining density altitude when the pressure altitude h, and density factor F are known.

where

ΔC_h = correction for rate of climb (ft. per min.)
Δb.hp. = b.hp.$_H$ − b.hp.$_m$ = difference between the specified and actual engine b.hp. for the airplane
η_c = propeller efficiency during climbing flight
W = gross weight of the airplane.

The propeller efficiency η_c can in general be estimated to within five percent, which is close enough for any climb calculation as far as the correction is concerned. The expression of Δb.hp. may be calculated in two parts. If it is first assumed that the air temperature does not affect the engine performance, then by observing the power from the power curves for the corresponding pressure and density altitudes, a difference of power of Δb.hp.$_p$ is obtained. This may be considered as the change in power due to change in air pressure for the assumption that standard temperature exists for both altitudes. As ΔH is the difference between the pressure and density altitudes,

$$\Delta\text{b.hp.}_p = \Delta H(d\text{b.hp.}/dH)$$

The variation of engine power with altitude may be expressed as

$$\text{b.hp.}_h = f\text{b.hp.}_0 \tag{9}$$

then introducing Eq. (6)

$$\begin{aligned}\Delta\text{b.hp.}_p &= \Delta H\text{b.hp.}_0(df/dH)\\ &= -\sigma_s(1-F)(df/d\sigma_s)\text{b.hp.}_0\end{aligned} \tag{10}$$

The variation of engine power with air temperature for pressure constant is found to be proportional to the square root of the ratio of standard to measured absolute air temperatures. This is identical to the familiar rule of reducing the engine power by 1 percent for each 10° F. that the carburetor air temperature is above the standard air temperature. Here the outside air temperature is used instead of the carburetor air temperature as any inherent rise in temperature before the carburetor is reached should be charged to the engine installation, as this same rise will occur under standard air conditions. The value of Δb.hp.$_t$ considered due to the effect of temperature on the engine power then becomes

$$\Delta\text{b.hp.}_t = (1-\sqrt{F})\text{b hp.}_h = f(1-\sqrt{F})\text{b.hp.}_0 \tag{11}$$

The total correction of power Δb.hp. is the sum of the above corrections giving

$$\begin{aligned}\Delta\text{b.hp.} &= \Delta\text{b.hp.}_t + \Delta\text{b.hp.}_p\\ &= \text{b.hp.}_0[f(1-\sqrt{F}) - (1-F)\sigma_s(df/d\sigma_s)]\end{aligned} \tag{12}$$

It should be observed that these corrections will always be of opposite sign. For example, on a hot day ($T_m > T_s$) the engine will have its power reduced due to temperature; hence an increment of power should be added to that measured. At the same time the density altitude will be greater than the pressure altitude and due to the reduction of power with altitude the engine will be using excess power at the pressure altitude h, requiring a reduction in power to obtain the specified power at the corresponding density altitude H.

If the power loading l_{t_c} during climbing flight is introduced,

$$l_{t_c} = W/\text{b.hp.}_0\eta_c \tag{13}$$

the final equation for ΔC_h is

$$\Delta C_h = (33{,}000/l_{t_c})[f(1-\sqrt{F}) - (1-F)\sigma_s(df/d\sigma_s)] \tag{14}$$

This equation shows that the power correction will depend upon: (1) Altitude, (2) thrust horsepower loading during the climb, (3) outside air temperature, and (4) type of engine installation.

It does not matter whether a fixed pitch or constant speed propeller is used, as long as a reasonable estimate of the propeller efficiency is made and the power loading based upon the actual brake horsepower that can be drawn from the engine at sea level during the climb. In reference (3) the variation of brake horse-

power with altitude is given for use with constant speed propellers as

$$f = (\sigma - 0.117)/0.883 \tag{15}$$

This equation fits very closely the altitude power variations shown on engine power curves for present-day engines with and without gear driven superchargers. For engines of this type the power at the critical altitude should be extrapolated to sea level; obtaining a fictitious power to be used in calculating l_{t_c}. In Fig. 3 curves for obtaining $\Delta l_{t_c} C_h$ are drawn based upon Eqs. (14) and (15).

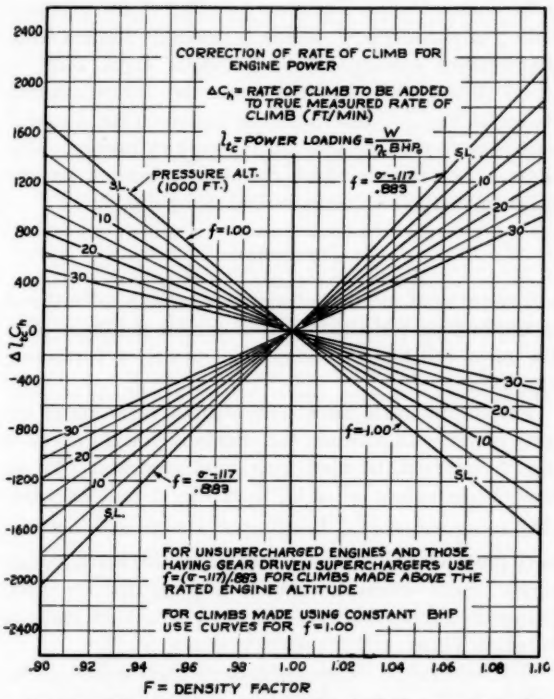
CORRECTION OF RATE OF CLIMB FOR ENGINE POWER
ΔCh = RATE OF CLIMB TO BE ADDED TO TRUE MEASURED RATE OF CLIMB (FT/MIN)
lte = POWER LOADING = W/(η BHP)
PRESSURE ALT. (1000 FT.)
f = (σ-.117)/.883
f=1.00
SL.
10
20
30
FOR UNSUPERCHARGED ENGINES AND THOSE HAVING GEAR DRIVEN SUPERCHARGERS USE f=(σ-.117)/.883 FOR CLIMBS MADE ABOVE THE RATED ENGINE ALTITUDE
FOR CLIMBS MADE USING CONSTANT BHP USE CURVES FOR f=1.00
Δlte Ch
F = DENSITY FACTOR

FIG. 3. Chart for calculating rate of climb corrections for airplanes having modern engines with or without gear driven superchargers.

For climbs made using constant brake horsepower the only correction necessary is that for air temperature. Curves for this case are also shown in Fig. 3.

With the use of Figs. 1 to 3 climbs for airplanes flying above and below the critical altitude of the engines may be conveniently reduced to standard conditions. For airplanes equipped with turbo-superchargers, similar curves may be drawn once the variation of power with altitude is known. A sample calculation showing the necessary steps in reducing a typical climb is given at the end of the paper.

EQUIVALENT CLIMBING ALTITUDE

Instead of correcting the true measured rate of climb C_{h_t} for engine power and referring it to the density altitude, values of C_{h_t} may be plotted against a special altitude known as the "equivalent climb altitude" and the same results obtained. This altitude for most engine installations occurs between the pressure and density altitude. It is interesting to calculate this equivalent climb altitude using the rate of climb corrections given in the first part of the paper, as then a more definite relationship between the two methods may be observed.

In Fig. 4 a portion of a rate of climb *vs.* altitude curve *s* diagrammatically shown for the condition $T_m > T_s$.

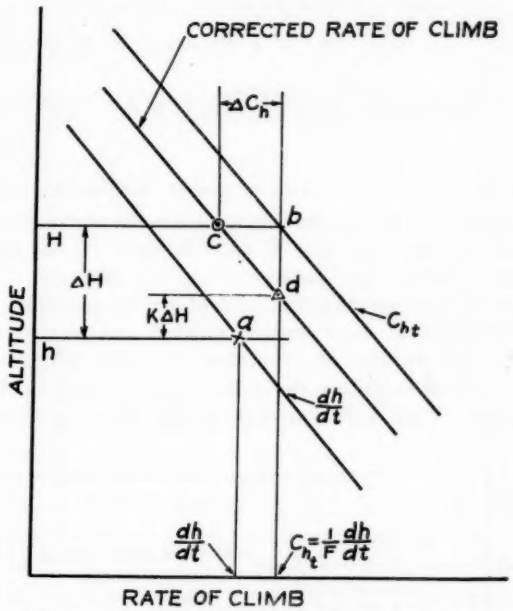

FIG. 4. Diagrammatic portion of a rate of climb *versus* altitude curve for a hot day, showing increments to be added to obtain the corrected rate of climb curve.

Point (*a*) corresponds to the measured rate of climb dh/dt at the measured pressure altitude h. Point (*b*) is the true rate of climb C_{h_t}, at the density altitude H, and would be the desired result if it were not necessary to correct for engine power. Correcting the climb for engine power reduces C_{h_t} by the increment ΔC_h giving point (*c*) which occurs on the rate of climb curve that would be measured on a standard day. It should be noted that this rate of climb curve intersects the C_{h_t} ordinate at a point (*d*) which is located between the pressure and density altitude. This is defined as the equivalent climb altitude. This altitude is calculated by the equation

$$h_e = h + K\Delta H \tag{16}$$

where h_e = equivalent climb altitude, K = equivalent altitude constant.

If the value of K is known, a curve of C_{h_t} vs. h_e may be plotted without resorting to any engine power correction, giving a curve identical to that which would be obtained on a standard day. Referring to Fig. 4,

$$\Delta H - K\Delta H = \Delta C_h/C_H'$$
$$K = 1 - \Delta C_h/\Delta H C_H'$$

where C_H' is the rate of change of rate of climb with altitude under standard conditions. Expressing the airplane performance in terms of the analytic performance equations given in references (3) and (4) the value $l_t C_H'$ is found to depend only on the performance parameter Λ and altitude. Introducing Eqs. (6) and (14),

$$K = 1 - \frac{33{,}000r}{\sigma_s(1 - F)(dH/d\sigma_s)l_t C_H'} [f(1 - \sqrt{F}) - \sigma_s(1 - F)(df/d\sigma_s)]$$
$$= 1 - \frac{33{,}000}{(dH/d\sigma_s)l_t C_H'} [(f/\sigma_s(1 + \sqrt{F})) - df/d\sigma_s] \quad (17)$$

where $r = l_t/l_{t_c}$ = ratio of power loading at high speed to that during the climb. From the above equation it is observed that K depends upon (1) the airplane performance parameter Λ, (2) altitude, (3) type of engine installation, and (4) air temperature.

Values of K have been calculated and plotted in Fig. 5 for the case of an airplane operating with constant speed propellers above the critical altitude of the engine. These values are based upon the performance curves given in reference (3) and are calculated for the case of $T_{vc} = 0.86$ as defined in the above reference The value of C_H' is found for a given Λ by plotting $l_t C_H$ against altitude and measuring the slope graphically. The value of r is determined once the T_v corresponding to the best climb speed is obtained.

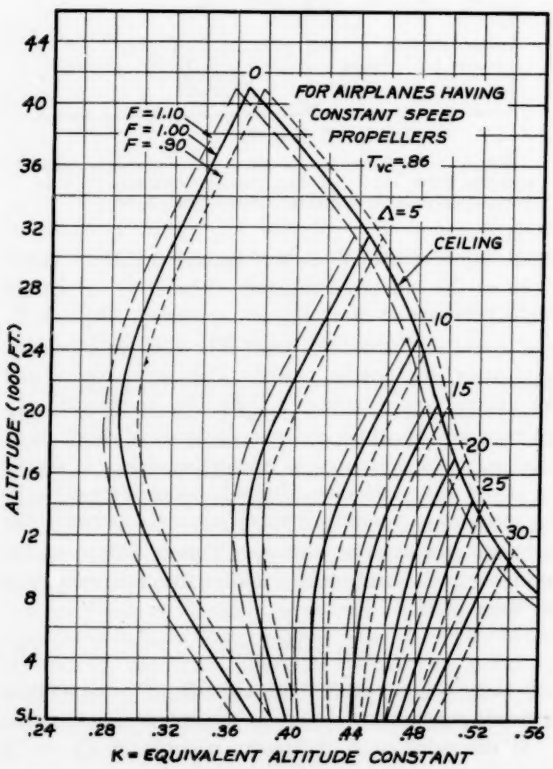

FIG. 5. Chart for obtaining the equivalent climb altitude constant K, to be used for airplanes having constant speed propellers and modern engines. Use only for climbs made above the rated engine altitude.

The value of F also causes K to vary but the variation is of secondary importance. When $F = 1.00$ it is noted that K has a finite value although ΔH will necessarily be zero, since the pressure and density altitude are identical. The curves of Fig. 5 are plotted for $F = 0.90$, $F = 1.00$, and $F = 1.10$ which includes the maximum temperature range that may be expected to be encountered. From an estimate of the absolute ceiling of the airplane, which is generally known from performance calculations or previous flight tests, a value Λ may be obtained from the curve marked ceiling in Fig. 5. Interpolating this chart for Λ and F values of K may be selected for various pressure altitudes. The sample climb calculation worked for the previous method is also reworked using Fig. 5.

DISCUSSION

The rational method of climb reduction as outlined in the first part of the paper, or similar methods, offer the most reliable and adaptable means of correcting climb data.

For climbs made using only a small variation of engine power with altitude the constant power curves of Fig. 3 may still be used with good accuracy. To do this obtain values of $\Delta l_{t_c} C_h$ from Fig. 3 and calculate ΔC_h using values of l_{t_c} based upon the actual power at each particular altitude. Cases where this method may apply occur when automatic carburetors are used below their critical altitude or when climbs are made at constant r.p.m. and manifold pressure.

The equivalent climb altitude method is just as accurate as the power correction method, when applied to airplanes of the proper engine installation. The time to calculate flight test data is not reduced over that required for the power correction method, but this method has the advantage that it permits one to inspect the flight test data and estimate whether the guaranteed performance is obtained. Relating the equivalent climb constant K to the airplane performance parameter Λ provides a definite means of selecting K. Fig. 5 shows that for airplanes having constant speed propellers the value of K increases with altitude, which means that when partial check climbs are made and the results extrapolated to obtain the absolute ceiling an underestimate of the ceiling may result if a constant value of K has been used for all altitudes. Another interesting item to note is that K increases for increasing values of Λ, which means that for the normal full engine power $K \cong 0.37$ for modern airplanes but may increase to over $K = 0.50$ for part power operation such as flying with one or more dead

engines. Values of K from Fig. 5 were compared with those calculated by Diehl[1] and found to vary in a regular manner but were consistently higher. This is believed due to the effect of using a constant speed propeller and a more modern engine power altitude relationship.

Sample Climb Calculation

This sample climb calculation is worked out by assuming a set of typical flight test data as given by columns (1), (2), and (3) of Tables 1 and 2. The values of dh/dt would normally be obtained by either plotting pressure altitude readings against time and measuring the slopes of this curve graphically or by calculating the slopes numerically from the tabulation of flight test data. This example corresponds to a typical warm day and includes a temperature inversion.

The airplane is assumed to have a gross weight W = 17,500 lb. and to be powered by two engines each rated at 750 b.hp. at 7000 feet. The airplane is equipped with constant speed propellers and during the climb below 7000 ft. the manifold pressure is assumed to be continuously adjusted to maintain a constant power of 750 b.hp.

Table 1 shows the climb reduction calculation based upon the method presented in the first part of this paper. For the climb calculations up to and including the 6000 ft. pressure altitude measurement the constant power correction is applied. At 6000 ft. pressure altitude the engine is still developing constant b.hp. but the corresponding density altitude is 8400 feet Hence, after the reduction for constant power is made, a further power correction for this point is necessary as the 8400 ft. density altitude is above the rated engine altitude. This calculation is shown at the bottom of Table 1 and the corrected climb curve plotted in Fig. 6.

Table 1

1	2	3	4	5	6	7	8	9	10
Pressure Altitude h	$\frac{dh}{dt}$	t_m	Density Factor F	ΔH	$\Delta l_{t_c} C_h$	ΔC_h	C_{h_t}	Corrected C_h	Density Altitude
Ft.	Ft. per min.	° C.	Fig. 1	Fig. 2	Fig. 3	Ft. per min.	Ft. per min.	Ft. per min.	Ft.
2,000	1030	22	0.962	1290	600	46	1070	1116	3,290
4,000	995	23	0.946	1810	780	59	1050	1109	5,810
6,000	950	25	0.927	2400	1000	76	1024	1002*	8,400
8,000	859	22	0.922	2520	−1280	−97	931	834	10,520
10,000	775	15	0.932	2160	−1060	−80	831	751	12,160

η_e = 0.70 (Estimated). l_{t_c} = 17,500/(2(750)/0.7860)(0.70) = 13.10.

* As the density altitude of 8400 ft. is 1400 ft. above the engine critical altitude of 7000 ft., the constant power value must be reduced for the loss of power in 1400 ft. At 7000 ft. f = 0.786 and at 8400 ft. f = 0.747, hence

Δt.hp. = (2(750)/0.786)(0.747 − 0.786)(0.70) = −52.1 hp.

Corrected C_h = 1100 − 98 = 1002 ft./min., where ΔC_h = −52.1(33,000 ÷ 17,500) = −98 ft.

Table 2

1	2	3	4	5	6	7	8	9
Pressure Altitude h	$\frac{dh}{dt}$	t_m	Density Factor F	ΔH	K	$K\Delta H$	C_{h_t}	Climb Altitude h_e
Ft.	Ft. per min.	° C.	Fig. 1	Fig. 2	Fig. 5	Ft.	Ft. per min.	Ft.
8,000	859	22	0.922	2520	0.430	1083	931	9,083
10,000	775	15	0.932	2160	0.432	935	831	10,935

From performance calculations the estimated absolute ceiling is 24,000 ft. From Fig. 5 for F = 1.0, H = 24,000 ft. the value of Λ = 11.

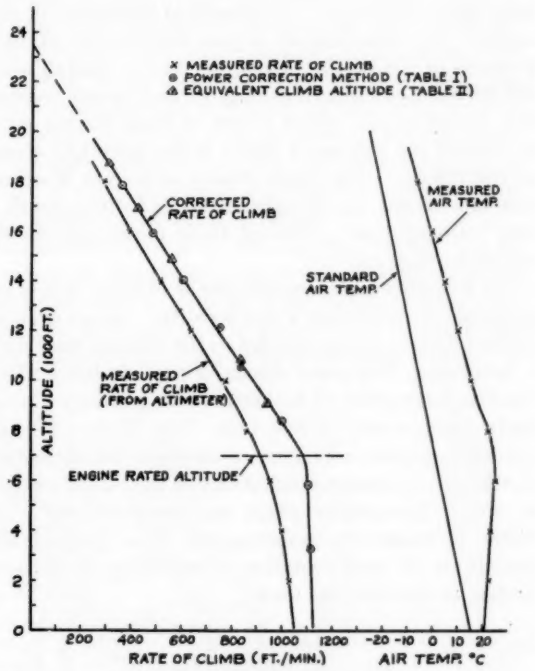

Fig. 6. Plot of the corrected rate of climb curve as calculated in Tables 1 and 2.

In Table 2 these same flight test data are corrected by the equivalent climb altitude method as discussed in the latter part of the paper. Both of these calculations agree, indicating the agreement between the two methods of reduction.

The calculations have been carried up to 18,000 ft., as indicated in Fig. 6; Tables 1 and 2 give the values up to 10,000 ft.

References

[1] Diehl, W. S., *The Reduction of Observed Airplane Performance to Standard Conditions*, N.A.C.A. Technical Report No. 297, 1928.

[2] Hall, S. S., and England, T. H., *Aircraft Performance Testing*, Sir Isaac Pitman & Sons, Ltd., London, 1933.

[3] White, R. J., and Martin, V. J., *Charts for Calculating the Performance of Airplanes Having Constant-Speed Propellers*, N.A.C.A. Technical Note No. 579, 1936.

[4] Oswald, W. B., *General Formulas and Charts for the Calculation of Airplane Performance*, N.A.C.A. Technical Report No. 408, 1932.

The Influence of Topography on Weather Forecasting at Salt Lake City, Utah

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Western Air Express

THE great influence of topography on weather phenomena, both on a large and a small scale, has long been recognized. Orographical influences in fact control to a considerable degree the climate of large portions of the earth. Thus, the heavy rainfall along the British Columbia, Washington, and Oregon coasts is due largely to the forced ascent of Polar Pacific air as it rises up the windward slopes of the mountain chains of this region. The desert climate of eastern Washington and Oregon, on the other hand, is a direct result of the "rain shadow" effect of these mountains on the region to their lee.

On a smaller scale, topography is of more or less importance in practically every locality. As an example of the influence of topography on the detailed weather of a small area, this paper discusses some features affecting the forecasting of detailed weather changes in the immediate vicinity of Salt Lake City, Utah. It is intended to explain only a few of the more interesting and characteristic synoptic situations of the Salt Lake area in which topography plays an important role. No claim is made to completeness, since innumerable variations of each situation could be given without adding to the essential ideas.

Topography

Salt Lake City lies in a deep intermountain valley in the Basin and Range physiographic province of the western United States, at an elevation of about 4200 feet above sea level. It is situated at the southeastern end of Great Salt Lake (see Fig. 1), and at the eastern border of the Great Salt Lake Desert. This is a roughly circular depression about 100 miles in diameter, with only a few small mountains within it. Most of its surface lies at about the same elevation as Salt Lake City. West of the Great Salt Lake Desert rise the high north–south ranges of eastern Nevada attaining an average height of about 9000 feet. East of Salt Lake City the imposing fault scarp of the Wasatch Mountains rises steeply to a rough upland surface some 9000–10,000 feet above sea level. This high surface continues to the north and south of Salt Lake City for a distance of over two hundred miles in each direction. Great salients, such as the Uinta Mountains, push eastward toward the Continental Divide.

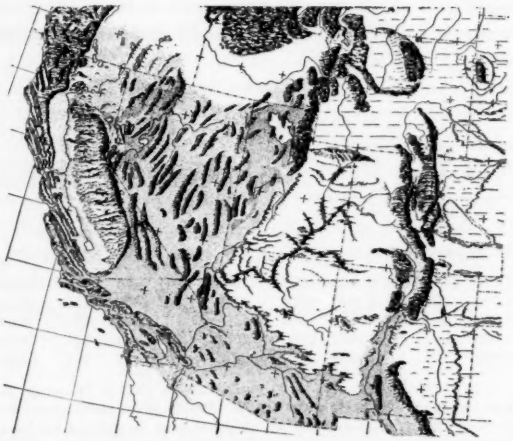

FIG. 1. (Courtesy of The Geographical Press, Columbia University.)

Some of the details of the topography in the immediate vicinity of Salt Lake City are shown in Fig. 2. Salt Lake City lies just east of the northern end of the Oquirrh Mountains, a small north–south range which

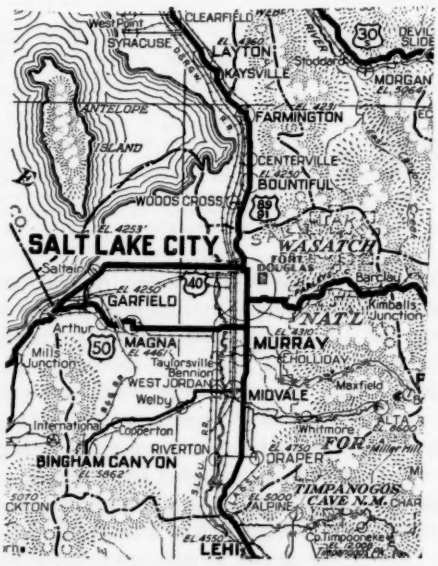

FIG. 2.

rises to a crest line of about 9500 feet. Salt Lake Valley continues to the south of the City for some distance, becoming narrower and narrower as the Oquirrh and Wasatch Ranges approach one another at Jordan Nar-

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rows, several miles northwest of Lehi. South of this point Utah Lake fills the open valley between the Wasatch Range and the Lake Mountains, a salient of the Oquirrh Mountains.

Effect of the Wasatch Mountains on Surface and Upper Winds in the Salt Lake Area

The general trend of the Wasatch Mountains, and particularly of the western scarp, is almost exactly north–south. Since prevailing winds of the region are in general west to northwesterly, the western slope of the range causes air to be lifted as it crosses from west to east. Most of the air column from the surface (about 4200 feet) up to approximately 14,000 feet is in fact lifted several thousand feet as it crosses the range.

Practically speaking, the lifting effect of the Wasatch Mountains is directly proportional to the sine of the angle that the wind makes with the mountain face. Air which flows at right angles to the trend of the range, (wind from the west), obviously is subjected to the greatest rate of vertical displacement or lifting. Winds nearly parallel to the range are practically unaffected. Winds blowing across the range from various directions between south-southwest and west and north-northwest are affected in varying degrees. This dependence of the rate of lifting on the wind direction is of the greatest importance, and must be carefully considered in all forecasting in this and other mountainous regions.

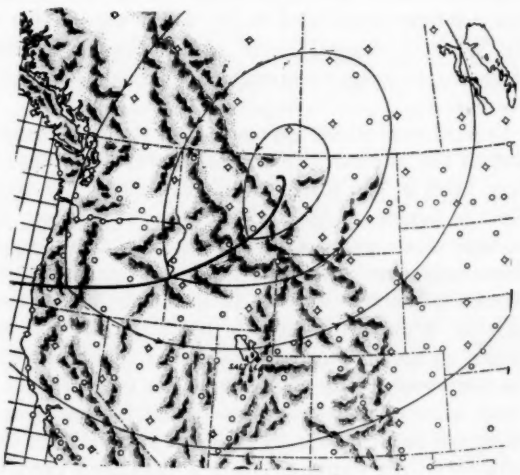

Fig. 3.

While orographical effects are concerned principally with the influence of topography on winds from *different directions*, it often will be found convenient for the forecaster to consider them rather in their relations to *frontal configurations*, since weather charts usually depict fronts rather than actual streamlines. Of course, the forecaster usually considers wind direction, especially when he is drawing isobars, but he commonly thinks first of the frontal system. For this reason, emphasis is placed on the relations between orographical effects and frontal configuration, rather than on actual wind direction, in most of the following discussion.

As an example of the widely different effects of the Wasatch scarp on winds from various directions, consider two cold fronts or cold front type occlusions approaching the Salt Lake area from the west (Figs. 3 and 4). In Fig. 3, the wind direction at low and intermediate levels preceding the front, is essentially *normal* to the mountain face. In such cases, the vertical component of the air passing over the Salt Lake region is a *maximum* for any given horizontal velocity. Fig. 4, however, where the front is oriented in a general north–south direction, the wind preceding it blows more or less *parallel* to the mountain face. In such cases, the vertical component is a *minimum* for any given horizontal velocity. For various other frontal configurations, and pressure distributions, the vertical component of the air in the region near the windward slope of the range assumes intermediate values.

The air *behind* the front, will naturally be affected by the mountain slope in an entirely different manner from the air preceding it. In Fig. 3, for example, the air following the front will tend to be lifted very little by the range, while in Fig. 4, it will be lifted considerably.

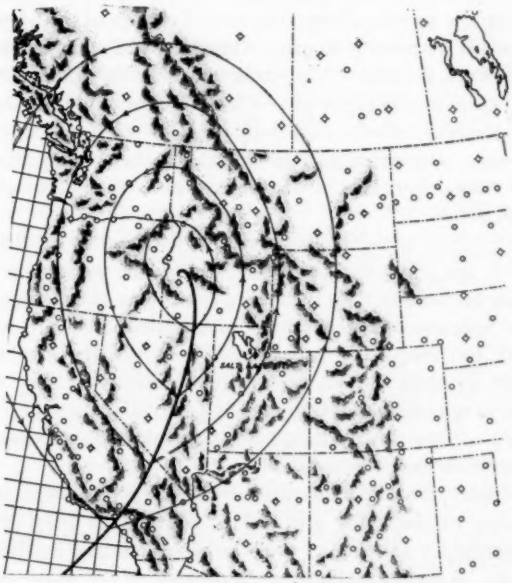

Fig. 4.

Usually, the general configuration of an approaching front (or of the pressure trough in which it lies) is sufficient to determine the approximate direction of the wind in its vicinity. The general pressure distribution of the entire region should be examined, of course, but in most cases the upper wind direction may be estimated with sufficient accuracy for most forecasting purposes from a study of the frontal configuration alone. This fact is mentioned because it is of considerable impor-

tance at times when pilot balloon ascents are not available. Generally a mere glance at the position and orientation of an approaching front will enable the forecaster to estimate the approximate magnitude of the vertical component of the air near a mountain range, both before and after the frontal passage.

Referring again to Fig. 3, prefrontal weather phenomena near Salt Lake City are considerably more severe here than in Fig. 4, since the lifting along the Wasatch scarp is greater in the first case. Clearing of the weather after a frontal passage, on the other hand, proceeds more rapidly in Fig. 3, since in this case the lifting of the air by the Wasatch Mountains is relatively slight.

All of these phenomena have been observed many times in the Salt Lake area, particularly since the author has been on the lookout for them. Needless to say, a recognition of them is of great assistance in forecasting, particularly for airline operations.

If pilot balloon observations are available, they may be used in determining the direction and velocity of the upper winds. However, the frontal orientation and the surface pressure system give a satisfactory indication of the amount of orographic lifting to be expected, even in the complete absence of pilot balloon data during widespread overcast conditions. Furthermore, in cases of rapidly moving fronts, the rate of change of the upper winds is frequently so great, that pilot balloon data are not of much value. The surface wind at Salt Lake City is rather frequently of some use in determining probable orographical effects, especially in cases when it is fairly strong. However, it often deviates rather widely from the actual direction of the air flow at intermediate and high levels.

Upper air pressure charts at the 5000 and 10,000 foot levels are often useful in determining the upper winds more accurately than by a mere inspection of the frontal and isobaric configuration. Such charts, however, are only too frequently not available at the times when they are most needed, and the refinements that they allow in upper wind determinations are usually not necessary. Their study should not be neglected, of course, whenever they are available.

Lastly, the isallobaric field should always be inspected rather carefully for any indications that it may give regarding a shifting of the wind from normal gradient flow. A strong isallobaric component of the wind very often exists during widespread storm conditions, and must be carefully considered in forecasting.

Forecasting

In many instances the shifting of the upper wind from a southerly to a southwesterly and then to a westerly direction as a front, oriented as in Fig. 3, approaches the Salt Lake area, will cause the rather sudden onset of squally weather. This is particularly true if the air over the region is conditionally unstable to a marked degree. This is very often the case during the winter, when fairly fresh Polar Pacific air is present much of the time. Such a sudden onset of squally weather which is often most baffling to the forecaster, is usually blamed on the passage of an upper front. In some cases this does occur, of course. In fact, the study of the passage of upper fronts over mountainous regions is one of the chief problems of the forecaster in the western portions of the United States.

However, many cases in which squally weather suddenly appears are definitely not related directly to any frontal activity at all. They are due simply to the abrupt onset of orographical precipitation caused by a shift in the upper wind. Whenever a front, oriented as in Fig. 3, approaches the Salt Lake area from the northwest at a time when conditionally unstable air is present, the forecaster can confidently forecast the onset of squally weather in the Salt Lake area. The time of beginning of the squalliness can be forecast if the time that the wind shifts from the southwest to the west-southwest can be estimated. This generally occurs when the front is about 200–250 miles away—a matter of 4 to 7 hours at the usual rates of frontal movement.

The approach of fronts oriented as in Fig. 4, on the other hand, is generally accompanied by very little prefrontal activity in the vicinity of Salt Lake City. This again is a very useful fact to use in forecasting.

The rate of clearing of the weather after a frontal passage is also important. The same orographical effects mentioned above can be used in this type of forecast. Winds following a front, which are parallel to the Wasatch Range, cause rapid clearing. Winds normal to the mountains result in long continued squally weather.

Upper fronts which approach from the west cause a shift in the intermediate and high level winds, and in some cases of the surface winds as well. (The latter effect is largely an induced effect, resulting from the passage of an upper pressure trough.) Thus, upper fronts may cause the same type of orographical phenomena as surface fronts. In fact some of the most puzzling weather situations in the Salt Lake area are caused by the approach of weak upper cold fronts from the northwest. The approach of this type of front at times when conditionally unstable air is present, may cause the onset of squally weather at Salt Lake City with very little warning. Only a meticulous examination of the weather chart, with very accurate placing of the upper front, and a consideration of probable orographic effects, will make possible a successful forecast under such circumstances.

Local Weather Variations in the Salt Lake Region

At times when orographical effects are pronounced, the southern end of the Salt Lake Valley often experiences markedly superior weather to the area near Salt

Lake City. Pilots often report, for example, that they can fly northward easily to within a few miles of Salt Lake City, only to find persistent and heavy squalls near the airport. Apparently in such cases, the Oquirrh Mountains act as a buffer for the region to their lee, whereas Salt Lake City itself does not enjoy this protection.

Precipitation records from the vicinity bear this conclusion out very clearly. Salt Lake City has an average annual precipitation of 16.23 inches. Revere (near Bingham Canyon), in the lee of the Oquirrh Mountains has but 13.83 inches. Even Lehi, well out away from the Oquirrh Mountains shows the "rain shadow" effect to some extent, with an annual precipitation of 15.31 inches.

It is interesting to note the wide variance of moisture in the region west of Salt Lake City. At Low, only 60 miles to the west, the average annual precipitation is but 5.89 inches, and at Wendover, about 100 miles to the west, the average is only 4.20 inches, approximately one-fourth of the amount at Salt Lake City. Both of these towns are well out on the Salt Lake Desert and are not affected by the orographical lifting of the Wasatch Mountains which is so important in the weather and the climate of Salt Lake City.

While the general concepts presented here are not new, their importance in short term airway forecasting has not been very widely recognized. Particularly in preparing forecasts for terminals in mountainous terrain, the meteorologist should give fully as much attention to orographical effects, as to purely frontal phenomena. In many cases the actual key to the solution of the forecasting problem lies in a full recognition of probable orographical influences.

Book Reviews

The Structure of Metals and Alloys, by WILLIAM HUME-ROTHERY; Institute of Metals, London, 1939; 118 pages.

This short book constitutes a revised edition of the original volume published in 1936. It sums up the structures and properties of metals and alloys from the point of view of modern atomic physics.

For those who have a sufficient background of knowledge of the physical theory of electrons and atomic structures, this book offers a very valuable compendium of atomic relationships among the metals and points out the very real progress that has been made in this field in recent years. To those who are unfamiliar with wave mechanics the book will illustrate the line of thought which is now in progress of development and which will in due time explain the fundamentals of metallic behavior.

Nearly everyone is familiar with the ordinary form of the periodic table. With the addition of the effect of electrons and their orbits, the use of the periodic table has been greatly extended and many very important relationships between crystal structure and mechanical behavior have been brought out. The equilibrium diagrams of various alloy systems have long been studied and used to predict the physical behavior of the resulting metals, but the reason for such behavior lies in the field of atomic physics rather than in that of thermodynamics and this short volume sums up the most recent thought in this field. The book is primarily addressed to those who wish a more complete explanation of metallic behavior rather than to engineers who have little interest or experience in atomic structures.

A valuable chapter concerns imperfections in crystal structures and deals very fundamentally with the strength of metals as exhibited in useful quantities rather than in perfect single crystals.

This book is a valuable addition to the student's library.

A. V. DE FOREST
Massachusetts Institute of Technology

Engineering Physical Metallurgy, by ROBERT H. HEYER; D. Van Nostrand Company, Inc., New York, 1939; 549 pages, $4.50.

The object of this book, as stated in the Preface, is to aid those making their first acquaintance with engineering metals and alloys. It is the author's hope that the book will be adapted to the instruction of non-metallurgical students and that, in general, it will bring up-to-date, in condensed and correlated form, information on the various materials, methods, and concepts of metals technology. It contains 253 illustrations, 70 tables, and more than 500 selected references.

The chapter titles give a general idea of the scope. They are: Pure Metals; Principles of Alloying; The White Metals and Their Bearing Alloys; Light Alloys; Die Castings; Copper and Its Alloys; Iron and Carbon Steels; Heat Treatment of Steel; Low and Medium Alloy Steels; Surface Treatment of Steel; Steel Castings; Welding; Cast Iron; High Alloy Steels; and Tool Steels.

Much care has been taken in the selection of both charts and micrographs. The tables are meaty. The text, while essentially a statement of metallurgical facts, contains welcome side lights on modern metallurgical theory. Although the author does not go out of his way to drag in controversial subjects, neither does he run away from them; in fact, he meets them squarely and handles them with tact and fairness. Furthermore, nothing is too "advanced" to be discussed. This is refreshing, because some authors feel that the "advanced" or new metallurgy is difficult and should be discussed only in treatises addressed to metallurgists. By this line of reasoning we would arrive at the conclusion that the new automobiles are more difficult to drive than the old-time models. We know that this is not so. The new metallurgy IS difficult. The factual information is so extensive that no real short cut is possible. But the new concepts offer the easiest and surest route to a working knowledge. The book is recommended, not only as a textbook, but also for reference.

ZAY JEFFRIES
General Electric Company

Diesel and Other Internal-Combustion Engines, by HOWARD E. DEGLER; American Technical Society, Chicago, Ill., 1938; 237 pages, $2.50.

This book briefly reviews the entire field of internal-combustion engineering, including gasoline, Diesel, and gas engines. Parts of two chapters deal with gasoline and Diesel aircraft engines. Chapters are included on the thermodynamics of internal-combustion engines and on the economics of Diesel power. Many engines of various type are described, and the illustrations are clear and numerous.

DANA W. LEE
National Advisory Committee for Aeronautics

Means for Suppression of Interference Burble

PAUL E. HOVGARD

Curtiss Aeroplane Division, Curtiss-Wright Corporation

LOW wing monoplanes using radial engines have been in use long enough so that the manner of designing a fillet for the juncture of wing and fuselage no longer presents a serious problem. Expanding fillets are drawn on preliminary design proposals with reasonable expectation of satisfactory functioning When the liquid-cooled in-line engine came into use, however, the interference burble again became a problem and new shapes had to be designed to suppress a premature stall caused by malformations at the leading edge of the wing near the fuselage. This paper deals with the latter type of stall, and particularly with the use of leading edge blisters as a remedy.

Symptoms

The symptoms of a premature stall may be any one of several faults reported by the pilot. It may manifest itself by tail buffeting at low speeds, by a dropping of the airplane just a moment before a normal landing was intended, or simply by failure to get the tail down for a landing. In all cases, careful measurements of minimum flying speeds will indicate a lower maximum lift coefficient than should have been anticipated.

These symptoms had shown up quite clearly in a previous experience of the Curtiss Company. A premature stalling had occurred on a high wing cabin fighter (Fig. 1) equipped with automatic interconnected slots and flaps. All the pilots who flew the airplane made

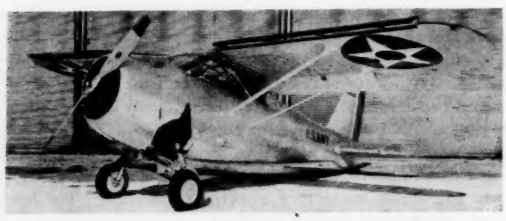

FIG. 1. High wing Cabin Fighter showing wing chord shortened at the root for pilot's visibility.

landings with the tail wheel still some distance in the air, and at least one pilot reported that the fault was that the whole airplane dropped suddenly before he was ready to land. When minimum speed measurements were made it was learned that they failed to meet guarantees by an appreciable margin. The designer, observing that the plane was never landed tail wheel first, experimented first with more powerful elevator control. This, however, did not remedy the difficulty.

The wing of this airplane was of constant chord from root to the rounded tip, except that the chord at the root was shortened locally to improve the pilot's vision. A fixed slot was inserted in this tapered segment of the wing, as shown in Fig. 2, resulting in a reduction in landing speed of approximately 5 miles per hour. This

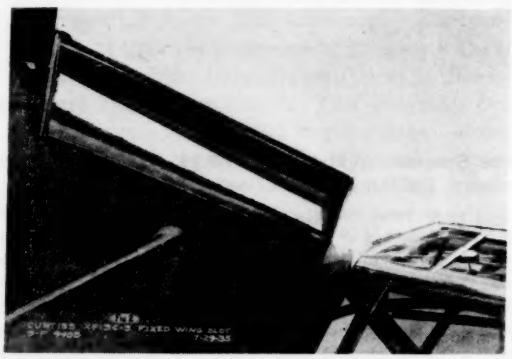

FIG. 2. Details of the fixed inset slot cut into the wing that successfully suppressed the interference burble.

slot, in preventing premature stall, maintained the downwash at the center of the wing, and the accompanying positive pitching moment from the down load on the horizontal tail surfaces. The original tail surfaces were retested and found to be adequate.

During tests of the first Allison pursuit built by Curtiss, pilots reported a tail buffeting when landing. Usually the pilot would come in rather fast, since the airplane was still new to him, and, as soon as the front wheels touched the ground, the buffeting would start and would continue for some time. The vibration was of such an amplitude that pilots were reluctant to fly the airplane. The problem was therefore referred to the wind tunnel for a solution.

Tests, however, had already been made on the airplane to determine whether or not the stall was caused by the scoops in the vicinity of the wing leading edge. Later, on the model, all the scoops were removed, without effect on the interference burble. On the other hand, later tests showed that the final answer, the blister, was effective whether the scoops were on or not.

Development of the Blister

The model was placed in the wind tunnel, tufts were attached along the fuselage and upper surface of the

Presented at the Pacific Coast Annual Meeting, I.Ae.S., Pasadena, California, June 16, 1939.

wing, and the action of the tufts observed as the angle of attach was increased. Fillets were applied with plasticine without the use of templates, and the effect on tuft behavior observed. The expanding fillet had been designed for the P-36 type airplane and had proven satisfactory. No modification of that fillet gave any measurable improvement. The Allison Pursuit was different from the existing P-36 airplane only in the power plant and position of the pilot (Fig. 3). The

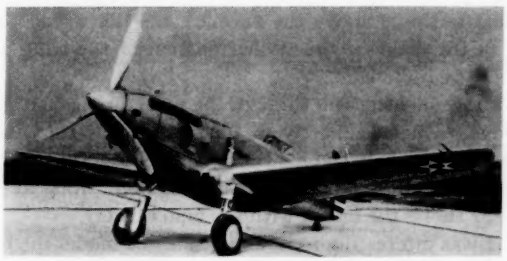

FIG. 3. First Curtiss Allison-powered Pursuit as originally constructed.

pilot's cabin was so far from the wing that it was hardly conceivable that it could be causing trouble. The source of trouble must therefore be the long pointed nose of the fuselage.

A test was then made with plasticine on the nose of the model to change it from a conical shape with base at the wing root to a cylindrical shape with a rounded nose. The test was not made as a possible cure, but simply to find out what effected the stall. This change in volume forward of the wing caused the stall to occur several degrees earlier. The experiment indicated clearly that the trouble lay primarily in the position of the wing on fuselage. This conclusion agrees in part with those of Jacobs and Ward,* that, in order to avoid interference burble, the wing should be cambered, and should be well forward on the fuselage.

In this particular case, with an airplane already built, a change in wing section or a change in wing location on the fuselage would be extremely difficult. The obvious thing to do for this particular case was to leave the wing as it was but to move the leading edge forward and downward locally at the wing root. The landing gear fairing provided a convenient stopping place for the outboard end of this new leading edge. The chord of the plasticine was slightly greater at the fuselage than at the outboard end.

This "blister" delayed the stall by about four degrees and was considered satisfactory on the model. Further investigation showed that, unless the blister increased both the chord and the camber, it was not effective. It is noteworthy that the first blister applied to the model is substantially the one which was installed on the airplane, producing the desired results (Fig. 4).

FIG. 4. The Curtiss Allison Pursuit after the No. 1 blisters had been attached.

WIND-TUNNEL TESTING PROCEDURE

Although the airplane appeared satisfactory, it seemed expedient at the time to continue the development of blisters for possible application to later designs.

The preliminary tests showed that plasticine was perfectly satisfactory for forming fillets and blisters. If it is applied with care the drag is no more than with a wood surface. It has the great advantage of permitting any modification in a very short time.

The usual procedure was to first cover the upper surface of the wing with tufts and observe tuft behavior as the angle of attack was increased or decreased. Then a very large blister was applied to each side that would be certain to suppress an interference burble, if it could be suppressed by a blister at all. From then on work was done on one side of the model only. The angle at which the wing recovered from the stall was noted as well as the angle at which the wing stalled. After the smallest blister having the desired effect was developed for one side the other side was made as nearly identical as possible. Tuft action was again observed and the blister on the side that stalled was altered. The stalling of one side always delayed the stall on the other side until it reached its proper stalling angle. The refinement of the blisters continued until the stall alternated from one side to the other, or until the wings recovered from the stall when the angle of attack was reduced not more than one degree.

So far all the work had been done with flaps down. Actually, the position of the flaps seems to have little effect on the interference burble. Ordinarily the airplane flies near its maximum angles of attack only with flaps down, so it is more significant to make the tests with that configuration.

The next step was to remove all of the tufts and determine the maximum lift with flaps down and the minimum drag with flaps neutral. From experience with tufts there were several types of blister and fillet combinations to be tried. For final adjustment of the plasticine, the angle of stall and recovery was observed by watching the balances, rather than by replacing the

* Jacobs, Eastman N., and Ward, Kenneth E., *Interference of Wing and Fuselage from Tests of 209 Combinations in the N.A.C.A. Variable Density Tunnel*, N.A.C.A. Technical Report No. 540, 1935.

tufts. This had the disadvantage of not showing up the weak side, so both sides had to be modified, hoping the change would improve, rather than mar the performance.

Whenever the blister and fillet resulting from the above procedure was taken directly to the model shop to have the new parts fashioned permanently in wood, the results were disappointing; the drag is usually higher and the maximum lift no better. So the model was taken to the drafting room or the mold loft to have templates made; then the templates were traced on to a drawing over the original wing sections and plan forms. Next the original wing sections were modified to conform to the approximate contour of the blister. The fillet radii were graduated uniformly to approximately the size of the plasticine fillets. A wood blister made in this manner gave lower drag, and the same lift as the original blister. This plan is now being followed for all blisters and fillets.

The blister developed previously was increased in chord and span in an attempt to reduce the divergence between stall as the angle of attack was increased and recovery from stall as the angle of attack was reduced. This required that the span and chord of the blister be increased approximately 60 percent (Fig. 5). The nature of the lift curve is shown in Fig. 6, blister No. 2.

FIG 5. Wind-tunnel model with No. 2 blisters.

One interesting characteristic of an interference burble resulting from malformations at the leading edge of the wing is that when the wing stalls on one side of the fuselage, the stall on the other side is thereby delayed. This is probably due to the flow across the fuselage from the stalled side, to the unstalled since the pressure on the upper surface would be greater on the stalled side and the flow across the fuselage would increase the pressure and decrease the lift of the unstalled side. When the two lift curve peaks are close together, as in Fig. 6, Blister No. 2, the stall will occasionally jump from one side to the other, when the model is held at an angle of attack between the peaks.

APPLICATION OF BLISTER TO TWIN ENGINE MONOPLANE

At the suggestion of Don Berlin, Chief Engineer of Curtiss Aeroplane Division, the blister was applied to a twin engine, midwing monoplane model. This airplane had characteristics which indicated it would respond to such treatment; when attempting to land slowly the bottom would fall out, and the nose would drop. At times the interference burble would be aggravated by some protruding body near the nacelle, such as an exhaust tail pipe above the nacelle; the tail would then be in the wake of the stalled portion of the wing and would be buffeted.

The model was run through the procedure as outlined above. One peculiarity of this model was that there was no "in-between" size or shape for the blister. Either it worked perfectly or it did not work at all. Fig. 7 shows the model with the final blister.

It was interesting to note that on this model the blister could not be made effective without a fillet at each end, at the junctures with fuselage and with engine nacelles. Often with the single engine models a fillet extending around the nose of the blister was not re-

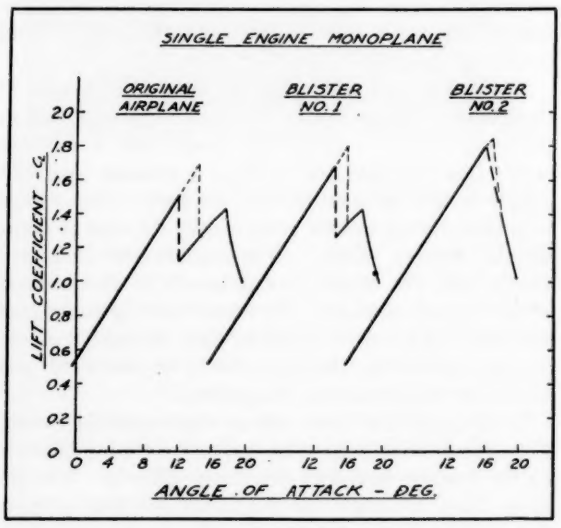

FIG. 6. Lift curves of the pursuit model.

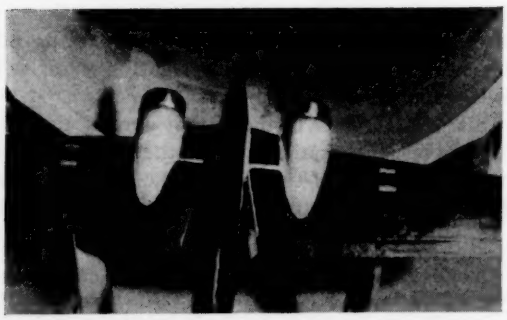

FIG. 7. Wind-tunnel model of twin engine monoplane.

quired and unless it were quite small it added to the drag.

This blister added 2 percent to the wing area. Based on the original area, the lift coefficient was increased 11 percent, and the drag coefficient was increased 2 percent.

The curves of Fig. 8 show the nature of the double peak in the lift curve, flaps down. The diving is clearly explained in the action of the moment curves without the blister. At an early angle of attack, the lift decreases a relatively small amount, but the pitching moment takes a large jump in the negative direction. With the blister on, the pitching moment changes but slightly when the airplane stalls.

The blister moved the aerodynamic center of the airplane forward on this model an unusually large amount, about $3^1/_2$ percent, and to obtain the original stability the center of gravity of the airplane should be moved forward a corresponding amount. On the single engine monoplanes, the forward movement of the center of gravity had been slightly less than half that amount.

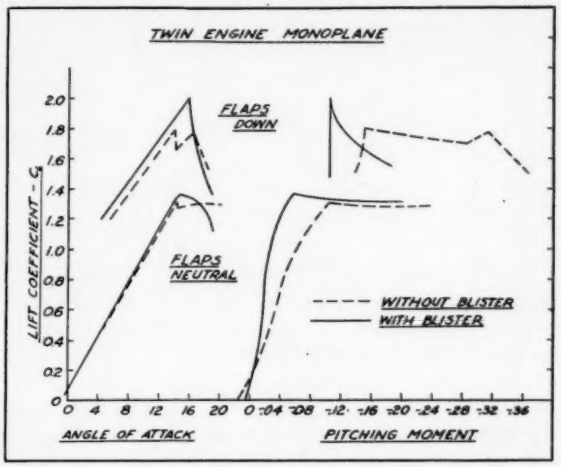

FIG. 8. Lift and moment curves of twin engine monoplane with and without blisters.

DRAG OF BLISTERS

Wind-tunnel tests of an early blister indicated that the maximum speed of the airplane was reduced about 2 miles per hour thereby. More recently a blister was designed that effectively delayed the stall and at the same time provided a speed increase of 3 miles per hour, as indicated by tunnel tests, over the airplane without blisters. Possibilities of a blister that will delay the stall and increase the speed are therefore indicated.

Book Reviews

Protective Coatings for Metals, by R. M. BURNS and A. E. SCHUH; Reinhold Publishing Corporation, New York, 1939; 407 pages, $6.50.

Corrosion of metallic structures results in the loss of millions of dollars each year through wasted material and is a menace to life because of the insiduous attack upon the strength of structures. In aircraft construction where comparatively thin sections are employed, it is particularly dangerous. Protective coatings are an attempt to control corrosion by interposing a protective coating between the metal and the corroding medium. This present work provides a synopsis of the properties and application of the most important industrial coatings.

This book is a revision of H. S. Rawdon's *Protective Metallic Coatings* written in 1927, extended to include organic and ceramic coatings and chemical treatment. It includes electroplating, hot dipping, metal spraying, sherardizing, metal cladding, paints and primers, slushing compounds, vitreous enamel coatings, and chemical treatment of surfaces. It presents a well-balanced discussion of the mechanism of surface preparation, application of various types of coatings, coating structure, protective value, and methods of testing. The subject is treated from the broad engineering standpoint rather than from that of the scientific specialist. Therefore, it is of most value to those who wish to obtain a general working knowledge of the entire field. However, due to the abundance of excellent illustrations, curves, and tables, it serves as a reliable reference book when practical data on a particular process are desired. The large number of references should satisfy those investigators who may desire to pursue a critical study of any particular phase of the subject.

The book is highly recommended as an outstanding contribution to the field of protective coatings for metals.

R. D. MACCART
Commander, U.S.N.

A Primer of the Internal Combustion Engine, by H. E. WIMPERIS; Constable and Company, Ltd., London, revised edition, 1939; 135 pages, 5s.

As a simple and easily understandable introduction to the theory and practice of the internal combustion engine, as given, for instance, in Mr. Wimperis' more advanced textbook, *The Internal Combustion Engine,* this book serves its purpose admirably. The first edition, which appeared in 1912, has been revised by Mr. W. J. Stern, for many years lecturer on Internal Combustion Engines for Aircraft at the Imperial College of Science.

Opening with a brief history of the internal combustion engine, the book continues with a discussion of the theory of heat, behavior of gases and vapors, the ideal and real engine, and fuels. It concludes with chapters on engine details and tests.

Carefully selected lists of problems at the ends of the chapters make the book particularly suitable for classroom use.

Diesel Engines, Operation and Maintenance, by L. H. MORRISON; American Technical Society, Chicago, Ill., 1939; 220 pages, $2.25.

This book was written for the purpose of presenting to students and beginners enough information on the Diesel engine to enable them to become skilled operators and repairmen. A brief outline of the Diesel principle and of the various types of engines is presented, followed by much useful information on the most practical methods of installation, adjustment, and repair of heavy-duty power Diesels. Non-technical language is used throughout, and the illustrations are excellent.

DANA W. LEE
National Advisory Committee for Aeronautics

Principal Stresses from Three Strains at 45°

H. W. SIBERT

University of Cincinnati

SUMMARY

An analytical method for obtaining the principal stresses from three strains at 45° is developed which is apparently quicker than any of the methods now in use.

INTRODUCTION

THE tensile or compressive stress in any direction at a point in a thin sheet of metal can be determined if the strains in any three directions through the point are known. Osgood and Sturm[1] gave a graphical solution of the problem based on a dyadic circle analogous to Mohr's circle for stresses or moments of inertia. Osgood[2] later gave an analytical solution for the case of four strains 45° apart. Beggs and Timby[3] exhibit a table for finding analytically the principal stresses from four strains 45° apart and claim that an experienced computer can calculate in six minutes the table required for any given point. Hill[4] developed a semi-graphical method based on three strains 45° apart by plotting to rectangular coordinates the curve $y = \cos 2\theta$ and then sliding over it a rectangular plot of the three measured strains divided by a calculated constant until these three points fall upon the cosine curve. Since one cosine curve suffices for the determination of the principal stresses at any number of points, Hill's method is considerably quicker than any of those previously mentioned.

A NEW ANALYTICAL SOLUTION

Let e_1, e_2, and e_3 be three strains at a given point such that e_2 and e_3 are, respectively, 45° and 90° clockwise from e_1. Hill[4] has shown that if all strains are divided by a constant, K, defined by the relation,

$$2K^2 = (e_1 - e_2)^2 + (e_2 - e_3)^2 \qquad (1)$$

the strain e at a clockwise angle, θ, from the maximum strain can be found from

$$e/K = (e_1/K + e_3/K)/2 + \cos 2\theta \qquad (2)$$

The cosine curve resulting from multiplying each side of Eq. (2) by K is shown in Fig. 1. From this figure the maximum and minimum values of e are, respectively,

$$e_{max.} = (e_1 + e_3)/2 + K \qquad (3)$$

$$e_{min.} = (e_1 + e_3)/2 - K \qquad (4)$$

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Moreover, Fig. 1 shows that the angle θ_m between $e_{max.}$ and the greater of e_1 and e_3 can be found from the relation

$$\cos 2\theta_m = |e_1 - e_3|/(2K) \qquad (5)$$

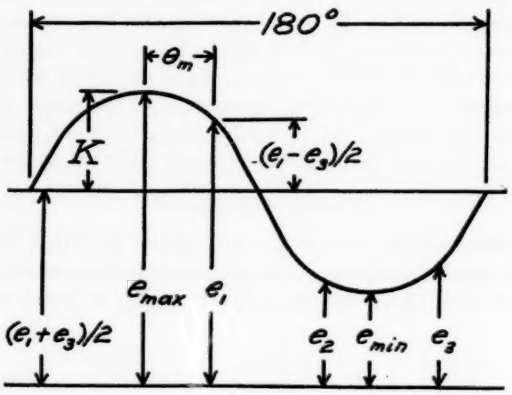

FIG. 1.

in which the two vertical bars are used to indicate the absolute value of $(e_1 - e_3)$. The direction of $e_{max.}$ with respect to e_1, e_2, or e_3 is determined from the three following conditions:

$|e_1 - e_2| > |e_2 - e_3|$, $e_{max.}$ is counterclockwise from the greater of e_1 and e_3 (6)

$|e_1 - e_2| < |e_2 - e_3|$, $e_{max.}$ is clockwise from the greater of e_1 and e_3 (7)

$|e_1 - e_2| = |e_2 - e_3|$, $e_{max.}$ is e_1, e_2, or e_3 (8)

Conditions (6), (7), and (8) are shown in Figs. 2, 3, and 4, respectively. The letters a, b, and c have been used to designate the plotted points for e_1, e_2, and e_3, respectively; and, for the sake of generality, the line of zero strain has not been shown in these figures.

After $e_{max.}$ and $e_{min.}$ have been found, the principal stresses, $\sigma_{max.}$ and $\sigma_{min.}$, can be obtained from

$$\sigma_{max.} = E(e_{max.} + \mu e_{min.})/(1 - \mu^2) \qquad (9)$$

$$\sigma_{min.} = E(e_{min.} + \mu e_{max.})/(1 - \mu^2) \qquad (10)$$

in which E is the modulus of elasticity and μ is Poisson's ratio. Obviously, $\sigma_{max.}$ is in the direction of $e_{max.}$ and $\sigma_{min.}$ is in the direction of $e_{min.}$

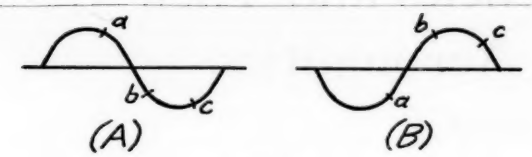

FIG. 2.

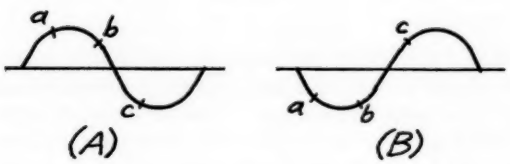

FIG. 3.

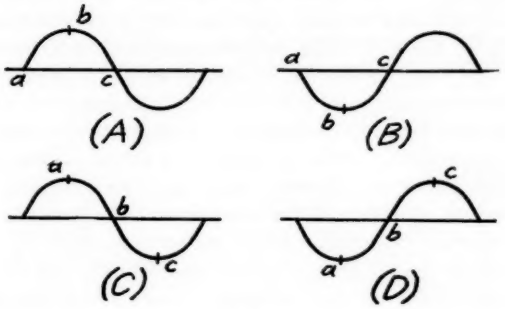

FIG. 4.

The maximum shearing stress, $\tau_{max.}$, occurs at 45° to the direction of the principal stresses and is given by the relation

$$\tau_{max.} = (\sigma_{max.} - \sigma_{min.})/2 \qquad (11)$$

Example 1. Given $e_1 = 235$, $e_2 = 65$, $e_3 = -55$ units.

$$2K^2 = 170^2 + 120^2 = 43{,}300 \quad \text{(Eq. (1))}$$
$$K = 147.1$$
$$e_{max.} = (235 - 55)/2 + 147.1 = 237.1 \quad \text{(Eq. (3))}$$
$$e_{min.} = (235 - 55)/2 - 147.1 = -57.1 \quad \text{(Eq. (4))}$$
$$\cos 2\theta_m = 290/294.2 = 0.9857 \quad \text{(Eq. (5))}$$
$$\theta_m = (9° 42')/2 = 4° 51'$$

$170 > 120$, $e_{max.}$ is 4° 51′ counterclockwise from e_1 (Condition (6), Fig. 2*A*).

Example 2. Given $e_1 = -235$, $e_2 = 65$, $e_3 = -55$ units.

$$2K^2 = (-300)^2 + 120^2 = 104{,}400 \quad \text{(Eq. (1))}$$
$$K = 228.5$$
$$e_{max.} = (-235 - 55)/2 + 228.5 = 83.5 \quad \text{(Eq. (3))}$$
$$e_{min.} = (-235 - 55)/2 - 228.5 = -373.5 \quad \text{(Eq. (4))}$$
$$\cos 2\theta_m = 180/457 = 0.3939$$
$$\theta_m = (66° 48')/2 = 33° 24'$$

$300 > 120$, $e_{max.}$ is 33° 24′ counterclockwise from e_3 (Condition (6), Fig. 2*B*).

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[2] Osgood, W., *Determination of Principal Stresses from Strains on Four Intersecting Gage Lines 45° Apart*, Bureau of Standards Journal of Research, Vol. 15, pages 579–581, 1935.

[3] Beggs, G., and Timby, E., *Interpreting Data from Strain Rosettes*, Engineering News-Record, Vol. 120, pages 366–370, 1938.

[4] Hill, H., *A Semi-Graphical Method for Analyzing Strains Measured on Three or Four Gage Lines Intersecting at 45°*, N.A.C.A. Technical Note No. 709, 1939.

Book Reviews

High-Speed Diesel Engines, by L. H. MORRISON; American Technical Society, Chicago, Ill., 1937; 243 pages, $2.50.

The fundamental principles of various types of high-speed Diesel engines and their fuel-injection systems are clearly and logically explained in non-technical language, followed by chapters on fuel requirements and general structural characteristics. Various American-made truck, bus, or stationary Diesels are then described in more detail, and two European engines of unconventional design are described. Many excellent illustrations are used throughout the book.

One chapter is devoted to aviation Diesel engines. The Mercedes-Benz Zeppelin Diesel, the Junkers Jumo, and the Deschamps engines are described. Although not concerned primarily with Diesel engines suitable for aeronautical use, this book should serve as a good starting point for anyone wishing to familiarize himself with the present state of development of lightweight Diesels.

DANA W. LEE
National Advisory Committee for Aeronautics

Les Flottes de l'Air en 1938, by R. GRUSS; Societe d'Editions Geographiques, Maritimes et Coloniales, Paris, 1939; 373 pages.

As it will probably be several years before directories of aircraft and aircraft engines giving the characteristics of new types will be available, it is fortunate that the second edition of this annual appeared before censorship became effective. By placing this alongside similar German, English, and American year books a fairly complete idea may be obtained of the leading aircraft and power plants of all countries.

It is particularly noticeable that in this French directory the descriptions of German and Italian airplanes are quite complete, but, like other annuals, the Russian section is sketchy.

A particularly useful addition to the illustrations and characteristics of airplanes is the brief description of the organization of the air force of each country and the current budget.

Annuals such as these are indispensable aids for reference and this contribution from the French viewpoint is certain to be helpful in determining the qualities of the aircraft that are available for use in the European conflict.

Ultra-High Frequencies and Their Application to Aeronautics

W. E. JACKSON

Civil Aeronautics Authority

THIS is a brief description of some of the work which is under way at the present time in the development of practical applications of ultra-high frequencies in the field of aeronautics. The Civil Aeronautics Authority operates a system of aviation radio aids serving the nation-wide network of civil airways in the United States. At present most of these facilities operate on low frequencies in the frequency range between 200 and 400 kilocycles. Frequencies of this order have their limitations due to atmospheric interferences, rain static, snow static, dust static, and multiple course phenomena, caused by reflections from the earth's surface. Recently the installation of a large number of position markers which operate on ultra-high frequencies has been completed. The frequency used for these markers is 75 megacycles. The purpose they fulfill is to provide the pilot with a definite fix over known geographical points. One type is known as the "Z" marker, sometimes termed a "positive cone-of-silence marker." A cone of silence exists over all radio range stations directly above the station and is characterized by a surrounding circular area of high-level signal intensity. When flying directly over a station, received signals rise to a peak immediately before and after passing through the so-called cone of silence. In order that the cone of silence may be positively identified and not mistaken for a somewhat similar fade which may occur in mountainous terrain due to momentary cancellation of the direct ray caused by reflections off mountain sides, it was decided to install positive cone-of-silence markers which would give a definite signal when over a radio range station. The Z marker lights a small indicator lamp on the instrument panel of a plane and in addition gives a continuous 3000-cycle audio signal in the pilot's headphones. The other type of ultra-high-frequency position marker is variously referred to as a "fan" or "curtain" marker and is indicated on aeronautical charts by an elliptical dotted line representing the location and shape of its field pattern. Type FM or fan markers are usually located along an airway from 20 to 30 miles from a range station for positive identification of a traffic control reporting point on the airway. This marker also lights an indicating lamp in the airplane giving at the same time a code signal in the headphones.

Ultra-high frequencies form the basis of the system which is now being developed for instrument landing. The elements of the instrument landing system are localizer, glide path, and markers. The localizer is merely a visual type of radio range. The glide path is really a vertical-plane field pattern contour of constant field strength. Inner markers are located at the edge of the field and outer markers approximately 2 miles from the edge of the field. The localizer operates on a frequency of 109.9 megacycles and is modulated at two audio frequencies, namely, 90 and 150 cycles. Each pattern overlaps and the point of equal field strength creates a radio range course. When a receiver is tuned to this frequency and two selective audio frequency circuits are used to operate a differential meter, the result is an indicating instrument which will deviate either to the right or the left of zero center, depending on which side of the course the plane is flying. The localizer sets up a straight course in a horizontal plane which extends through the center of the runway. The glide path operates on a frequency of 93.9 megacycles and is modulated at an audio frequency of 60 cycles. This provides a glide path which is essentially parabolic. This path is usually adjusted to cut through the field of the outer marker at an altitude of 600 feet. The altitude of the plane at the edge of the field is approximately 60 feet, making the point of ground contact approximately 3000 feet from the far end of the runway. The ultra-high-frequency markers are located on the approach path to identify the edge of the field and a point on the localizer course approximately 2 miles from the edge of the field. The outer marker is modulated at a frequency of 400 cycles and operates a purple indicator light in the cockpit of the airplane. This marker is keyed to transmit dashes continuously. The inner marker is located at the edge of the field and is modulated at 1300 cycles per second. It keys dots continuously which operates an amber indicator light in the cockpit. In order to accommodate different wind directions, a complete complement of equipment is provided for each runway.

This system, combined with a remote control equipment and complete monitoring facilities, is essentially the type of equipment the Civil Aeronautics Authority is installing for trial at Indianapolis. Further development is being carried on in order to obtain a straight-line glide path which appears to offer several definite advantages. The principal advantage of a straight path is that the glide angle remains constant regardless of receiver sensitivity. This problem is being attacked

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from two different angles. The first is to construct essentially a localizer in the vertical plane modulated on two frequencies but turned on its side in order to create a localizer in the vertical plane. Similar work is now being carried on at two different frequencies—109.9 megacycles and approximately 500 megacycles.

Probably the most important phase of the C.A.A. experimental work is the development of ultra-high-frequency ranges to be used on the Federal airways of the United States. Development work during the past two years has indicated that greatly improved courses may be obtained when utilizing ultra-high frequencies. The basic advantages are improved reception under conditions of atmospheric static or rain static, and a remarkable decrease in the multiple course effect. The initial cost of an ultra-high-frequency range station compared to a conventional low-frequency range represents an enormous saving, chiefly due to the reduced cost of the antenna system. Preliminary work has been carried to a point where the Civil Aeronautics Authority plans to install a complete chain of ultra-high-frequency radio ranges on the airway between Chicago and Newark in order to test them under regular service conditions. Flight tests already conducted have definitely indicated that the results obtained under severe static conditions are vastly superior as compared to radio ranges operating in the 200–400 kilocycle band.

This is only a brief outline of some of the aeronautical uses for ultra-high frequencies. The results thus far obtained are most encouraging. Ultra-high frequencies offer great promise of becoming increasingly important to aviation.

Book Reviews

ABC of Aviation, by VICTOR W. PAGÉ; The Norman W. Henley Publishing Company, New York, second edition, 1939; 418 pages, $2.50.

Col. Pagé has brought the 1928 edition of this book up-to-date and has compiled in the same simple form the principles governing the design, construction, and flight of airplanes and airships. While the book is intended for the general reader, much information is included which will be useful for those who intend to study aeronautics seriously or become pilots. The whole range of aeronautics is compressed into this small volume. Questions at the end of each chapter will impress on the reader's memory the essentials which he is expected to grasp.

It is profusely and discriminatingly illustrated. As a handbook for the beginner the book will continue to be as useful as it has been during the past ten years.

Physical Meteorology, by JOHN G. ALBRIGHT; Prentice-Hall Inc., New York, 1939; 392 pages, $5.35.

It is the stated purpose of the author to explain the various aspects of meteorology in terms of physical principles. Insofar as it is practicable he has done so. There is necessarily a considerable amount of purely descriptive material required in a text covering such a wide field. The scope of the book may be judged from the fact that following an introductory chapter, the nineteen others are composed of four dealing with the properties of the atmosphere, four on heat and thermodynamics, three on mechanics, four primarily of descriptive character, two on atmospheric electricity, and one each on atmospheric acoustics and optics.

The author uses physical principles and mathematical reasoning in his development, for which a knowledge of physics and the calculi are prerequisites. However, the mathematics is held to a minimum and should not greatly hinder a non-mathematical student.

Throughout the book formulas are derived and examples worked in detail. This is a very good feature in principle; however, in some instances neither sufficient detail nor a satisfactory reference is given to avoid confusion on the part of the student.

Some explanations of instruments and processes are very well done. Also some of the definitions are emphasized and expressed very clearly in order to correct any false ideas which the student may have.

There are statements in the book which are likely to mislead a student who does not have the advantage of accompanying personal instruction. Two of these are important because of their fundamental nature:

The treatment on page 132 of the density of water vapor. In this development the density at N.T.P. is stated to be 801 grams per cu. meter. This tacitly assumes that water vapor acts as a perfect gas under the conditions specified. Water vapor exerting a pressure of 760 mm. hardly approximates a perfect gas at 100°C., much less at 0°C. Although, as a means of obtaining a numerical coefficient, this procedure undoubtedly has arithmetical advantages, its use in a textbook emphasizing physical methods is of questionable merit.

The lapse-rate of 3.5°C. per 100 meters is the auto-convective lapse-rate and is not necessary "If the density of the air on rising is to be the same as the air just above it" (page 194). The necessary lapse-rate in such a case is merely the adiabatic (unsaturated or saturated as the case may be). With a lapse-rate exceeding 3.5°C. per 100 meters the density *increases* with height, an obviously *unstable* condition.

The literature referred to throughout the text by number is listed in an appendix which also includes an extensive bibliography. The book concludes with a detailed and useful index.

CHARLES M. LENNAHAN
U.S. Weather Bureau

Il Volo in Italia, by FEDERIGO VALLI and ANTONINO FOSCHINI; Editoriale Aeronautica, Rome, 1938; 405 pages.

Few people realize the long historical background of aviation to be found in Italian literature and art. The distinguished editor, Federigo Valli, and Sig. Foschini have compiled a work which is a great credit to Italian aviation. Pictorially it is a work of art as well as a history, hundreds of illustrations being reproduced in gravure and color.

Beginning with the legendary epoch of flight the history is brought down to recent times by a description of activities of the Italian Air Force in Spain and Abyssinia and the noteworthy flights made by famous Italian pilots.

Compiled with painstaking care and in good taste the book is a testimonial to the high position Italy occupies in the development of aeronautics.

Institute Notes

Dr. Millikan to Give Wright Brothers Lecture

Mr. E. F. Relf, Superintendent of the Aerodynamics Department at the National Physical Laboratory, England, who was scheduled to deliver the third Wright Brothers Lecture, has notified the Institute that it will be impossible for him to prepare the lecture or leave England at this time. The committee in charge has accordingly selected Dr. Clark B. Millikan, a Founder Member and Fellow of the Institute and Associate Professor of Aeronautics at the California Institute of Technology, to deliver the lecture. The subject will be "The Influence of Running Propellers on Airplane Characteristics."

As previously announced, through the courtesy of Columbia University, the lecture will be held at the Pupin Physics Laboratories, Broadway and 120th Street, New York, on December 16, 1939, at 3:00 p.m. It will be preceded by a luncheon in honor of Dr. Millikan at the Columbia University Faculty Club at 1:00 p.m. An interesting program of luncheon talks is being arranged.

Rotating Wing Aircraft Meeting

The Second Annual Rotating Wing Aircraft Meeting sponsored by the Philadelphia Branch of the Institute, which was announced in the October issue of the Journal, will be held on November 30 and December 1, 1939, in the lecture hall of The Franklin Institute, Benjamin Franklin Parkway at 20th Street, Philadelphia. As for the 1938 meeting The Franklin Institute and the Aero Club of Pennsylvania are generously giving their aid and support.

Special arrangements have been made with the Penn Athletic Club, 18th and Locust Streets, for overnight guests. There will be a registration fee of $1.00 to cover printing costs for the meeting. The luncheon on Friday will be $1.00, and the banquet, which ladies may attend and at which dress is optional, will be $3.00 per person. Prominent leaders in aviation will speak. It is possible for those coming for the meeting to attend the Army-Navy football game on the afternoon of December 2nd.

The program of papers listed below covers all phases of the subject, including both technical and semi-technical contributions which promise to be of considerable interest and importance.

Thursday, November 30th, 1:00 p.m.

Registration, Planetarium Lobby

2:00 p.m.

Capt. Frank Gregory, Chairman

Lt. E. S. Nichols, U.S. Army Air Corps, *Army Tactics with Rotary Aircraft.*

John M. Schuckers, Hilliard Clutch Corporation, *Rotor-Craft Drive Systems.*

Arthur M. Young, Paoli, Pennsylvania, *A New Parameter of Lifting Rotors.*

Capt. John M. Miller, Eastern Air Lines, *Roof Landing Problems.*

8:00 p.m.

Agnew E. Larsen, Chairman

Igor Sikorsky, Vought-Sikorsky Aircraft, United Aircraft Corporation, *Commercial and Military Uses of Rotating Wing Aircraft.*

Friday, December 1st

9:30 a.m.

Dr. Alexander Klemin, Chairman

C. E. McCollum, TWA, *Economic Significance of Central-City Landings on Passenger Traffic.*

Joseph S. Pecker, Machine and Tool Designing Company, *Mechanical Design in Rotary Aircraft.*

E. Burke Wilford, Pennsylvania Aircraft Syndicate, *Rotor-Craft and Combination Types.*

Paul H. Stanley, Pitcairn Autogiro Company, *Treatment of Performance Losses on Rotors with Center Cut-Outs.*

Hugh Mulvey, Kellett Autogiro Corporation, *Stress Analysis of Rotor Blades.*

12:30 p.m.

Luncheon, Hollands, 116 N. 19th Street

2:00 p.m.

Dr. George W. Lewis, Chairman

F. J. Bailey, Jr., N.A.C.A., *Photographic Observations in Flight of the Stalling of Rotating Wings.*

Harris S. Campbell, Glenside, Pennsylvania, *Rotor Controls.*

Richard H. Prewitt and Robert A. Wagner, Kellett Autogiro Corporation, *Rotor Vibration Problems.*

Dr. Alexander Klemin, New York University, and Lt. Victor Haugen, U.S. Army Air Corps, *Stability in Rotary Aircraft.*

7:00 p.m.

Banquet (Ladies Invited—dress optional)

Locust Room, Penn Athletic Club, 18th and Locust Sts.

W. Lawrence LePage, Toastmaster

Saturday, December 2nd.

Roof, Philadelphia Post Office, 30th and Market Streets

To see scheduled Landing and Take-Off as guests of Eastern Air Lines

9:10 a.m.—Take-off P.O. Roof
9:35 a.m.—Landing from Camden
10:00 a.m.—Ceremonies with address
10:35 a.m.—Take-off P.O. Roof
11:30 a.m.—Landing from Camden
12:15 p.m.—Take-off P.O. Roof.

Announcement of meeting time will be made Friday afternoon.

Branches

Aeronautical University. At a meeting on June 20th the following officers of the Student Branch were elected: Charles Lasher, Chairman; Herbert De Weese, Vice-Chairman; Robert Stebley, Treasurer; Robert Rosner, Secretary. At the same meeting Major Vest of the C.A.A. spoke on the duties of the C.A.A. and methods of determining the airworthiness of new designs. The following activities occurred during the summer: August 9th, tour of inspection through American Airlines shops, hangars, and offices; August 11th, motion pictures furnished by the Pittsburgh Steel Corporation on making of seamless steel tubing; August 25th, motion pictures on arc welding furnished by The Linde Air Products Corporation.

Catholic University of America. The first meeting of the school year, held on October 19th, was attended by about fifty students. Interesting talks on the functions of the Institute by Dr. Munk and Mr. Bockrath were well received.

University of Cincinnati. At the first meeting of the school year James Dugan was elected to the vacated office of Treasurer. Plans for future meetings were discussed. At a meeting on October 7th George Selvin spoke on the "Curtiss-Wright Model 20," adding a short discussion of de-icing equipment.

University of Detroit. At the first meeting of the school year Kenneth Mattucha of the C.A.A. spoke on "Airway Traffic Con-

trol" and Robert Olsen of American Airlines on "Airline Requirements." Mr. Olsen also presented the motion picture, "The American Way." The meeting was very successful in both attendance and interest. The officers of the Branch for the present school year are: Kenneth E. Smith, Chairman; Stanley Siggs, Vice-Chairman; Charles R. Carrier, Secretary; Gerald W. Cloeman, Treasurer; Prof. Peter Altman, Honorary Chairman.

University of Minnesota. At a joint meeting of the Student Branch with the University of Minnesota Flying Club, the following new officers of the Branch were introduced: Norvin Erickson, Chairman; Stan Church, Vice-Chairman; Don Crowley, Treasurer; and Ralph Schreiber, Secretary. Professors Barlow, Piccard, Brush, Boehnlein, Serebreny, and Ruszaj gave short talks.

North Carolina State College. The first meeting of the school year was held on September 19th. Captain W. J. Tate of Kitty Hawk gave an interesting account of his associations with the Wright Brothers during their stay in North Carolina. The second meeting, in the form of a smoker and reception for the new students, was held on September 22nd. Prof. L. R. Parkinson spoke on the organization of the Institute, and H. R. Crawford outlined the preliminary plans for the year's activities. Approximately sixty-five students and members of the faculty were present.

Seattle. At a meeting of the Branch on September 27th, J. A. Goodhue of Hamilton Standard Propellers, spoke on "Development of the Hydromatic Propeller" and "Recent European Aircraft Developments." Interesting discussions followed the presentations. One hundred and twenty-one members and affiliates attended the meeting.

Tri-State College. The first meeting of the school year was held on October 16th. Professor Lawrence D. Ely gave an interesting digest of the paper on "Instrument Flight Instruction," prepared by the Boeing School of Aeronautics. This was followed by a discussion of blind landing.

Personnel Opportunities

The Personnel Bureau serves individual members, as well as organizations seeking to employ aeronautical specialists. Any member or organization may have requirements listed without charge.

Wanted

Michigan Aircraft Manufacturer has attractive engineering positions open for experienced engineers familiar with all-metal construction; group leaders, layout men, and design draftsmen for wing, fuselage, electrical surface controls, landing gear, and power plant. Write, giving education, experience, salary expected, and when available. Reply Box 94, Institute of the Aeronautical Sciences.

Changes in Membership

The following changes in the membership of the Institute have occurred since the publication of the previous issue of the Journal.

Elected to Member Grade

Ellinger, Ralph LaVon, M.I.Ae.S.; Asst. Chief Engineer, Transcontintental & Western Air, Inc.

Hood, Manley John, B.S.; M.I.Ae.S.; Assoc. Aero. Engineer, N.A.C.A.

Moles, Howard R., B.S. in M.E.; M.I.Ae.S.; Asst. Project Engineer, St. Louis Airplane Div., Curtiss-Wright Corp.

Myers, George Francis, B.S. in M.E.; M.I.Ae.S.; Patent Attorney. (See W. W. in Eng.)

Seitz, Clifford Peter, Ph.D.; M.I.Ae.S.; Instructor, Dept. of Psychology, Univ. Alabama.

Tauson, Peter Otton, M.S. in M.E.; M.I.Ae.S.; Stress Analyst & Aerodynamicist, Rearwin Airplanes & Engines, Inc.

Elected to Technical Member Grade

Dallenbach, Frederick, Aero. Engineer, Lockheed Aircraft Corp.

Hawkins, Willis Moore, Jr., B.S. in Ae.E.; Aero. Research Engineer, Lockheed Aircraft Corp.

Korody, Paul, Stress Analyst, Rearwin Airplanes & Engines, Inc.

MacDonough, Edward Paul, B.S. in M.E.; Engineer, Vought-Sikorsky Aircraft Div., United Aircraft Corp.

Wickwire, Austin, Design Draftsman, Douglas Aircraft Co.

Transferred from Member to Associate Fellow Grade

Elias Moness, Engineer, Douglas Aircraft Co.; F. R. Shanley, Chief Engineer, Curtiss-Wright Technical Inst.; James B. Taylor, Jr., Pres., Taylor-Ainsworth, Inc.

Transferred from Technical Member to Member Grade

Charles I. Lathrem, Chief Engineer, Propeller Div., Canadian Car & Foundry Co.

Transferred from Student Member to Technical Member Grade

Barnard S. Adams, Meteorologist, Pan American Airways; Charles M. Adams; John F. Aldridge, Jr., Engineer, United Aircraft Corp.; Warren J. Allen, Jr., Grumman Aircraft Engineering Corp.; D. H. Andrews, Jr., Experimental Engineer, Chandler-Evans Corp.; Lt. Basil P. Antonenko, Engineering Div., Water Dept., City of Pasadena, Calif.; Howard H. Ash, Design Engineer, Republic Aviation Corp.; A. Avgerenos, Clerk, Morris Wood & Sons; Donald D. Baals, Jr. Engineer, N.A.C.A.; A. T. Barbero, Instructor, Lincoln Airplane & Flying School; Lt. George Francis Beardsley, Sr. Aviator, U.S. Navy; C. F. Bell, Jr., Draftsman, Glenn L. Martin Co.; W. T. Bell, Draftsman, Douglas Aircraft Co.; Harold Bennett, Engineer, Boeing Aircraft Co.; V. E. Bergdolt, Asst. Engineer, American Creosoting Co.; Vincent J. Berinati, Engineer, Howard Aircraft Corp.; Irving Berler, Aero. Engineer, Curtiss Aeroplane Div., Curtiss-Wright Corp.; William N. Bradley, Aero. Engineer; Edward Burd, Aero. Engineer; Aviation Cadet R. R. Burns, U.S. Marine Corps Reserve; Harry B. Calvert, Boeing Aircraft Co.; John E. Cameron, Engineer, Boston-Maine Airways; Myron A. Cantor; Roy I. Case, Jr., Draftsman, Consolidated Aircraft Corp.; Dr. A. C. Charters, Jr., Research Fellow, Calif. Inst. of Tech.; Charles Christenson, Grumman Aircraft Engineering Corp.; Mark H. Clarkson, Aero. Engineer, Douglas Aircraft Co.; Fred William Clayton, Jr., Chief Engineer, Airmantech; Lt. L. D. Coates, Naval Aviator, U.S. Navy; Rossa W. Cole, Instructor in Aircraft Engines, New York Univ.; R. I. Congdon, Meteorologist, United Air Lines Transport Corp.; Robert N. Conway; Walter Cornelius, Jr. Engineer, General Motors Research Lab.; John J. Crane, Student, Wayne University; A. B. Croshere, Jr., Aero. Engineer, Douglas Aircraft Co.; H. H. Crotsley, Aero. Engineer, Curtiss Aeroplane Div., Curtiss-Wright Corp.; J. R. De Hart, Meteorologist, Eastern Air Lines; I. Charles Dickens, Jr. Engineer, Howard Aircraft Corp.; Howard B. Dilatush, Jr., Aero. Engineer, Ryan Airplane Co.; Walter A. Dommers, Asst. to Pres., Huckins Yacht Corp.; Daniel Don, Stress Analyst, Briegleb Aircraft; John W. Draper, Jr. Aero. Engineer, N.A.C.A.; Oldrich Dudek, Engineer, Howard Aircraft Corp.; Orville R. Dunn, Engineering, Douglas Aircraft Co.; Christopher Dykes, Fellow in Aeronautics, Cambridge University, England; J. Owen Eames, Instructor, Casey Jones School of Aeronautics; Geo. L. Fieldson, Mechanic, American Airlines; David Flushman; Andrew A. Fogliano, Engineer, Vega Airplane Co.; Harold E.

Francis, Exp. Engine Tester, Wright Aeronautical Corp.; Fred S. Frank; M. Frankel, Jr. Aero. Engineer, U.S. Naval Aircraft Factory; William Frantz, Stress Analyst, Howard Aircraft Corp.; W. Robert Freyvogel, Jr. Aero. Engineer, U.S. Army Air Corps; Lt. E. L. Gilbert, U.S. Marine Corps; Mellor A. Gill; Edward K. Grimes, Jr. Aero. Engineer, U.S. Army Air Corps; Richard L. Grow, Boeing Aircraft Co.; W. D. Hall, Aero. Engineer, Aeronautical Corp. of America; Robert B. Hamilton, Shop Liaison Engineer, Lockheed Aircraft Corp.; Duncan Harding, Draftsman, North American Aviation, Inc.; Jack D. Harshman, Wind-Tunnel Operator, Univ. of Washington; Leslie F. Hauck, Detailer, Vega Airplane Co.; Edward A. Hawkens, Jr., Mech. Engineer, Jones & Laughlin Steel Corp.; W. Heath, Jr.; Clarence E. Hill, Radio Operator, United Air Lines Transport Corp.; T. Gardner Hill, Aero. Engineer, Glenn L. Martin Co.; Jerome Hoffer, Jr.; George E. Holback, Aero. Engineer, Glenn L. Martin Co.; Gerald E. Hotchkiss, Lockheed Aircraft Corp.; W. Lavern Howland, Research Engineer, Lockheed Aircraft Corp.; Shu Kuang Hu; R. L. Hundley, Jr. Detailer, Lockheed Aircraft Corp.; Lt. A. McB. Jackson, Naval Aviator, U.S. Navy; Martin A. Jackson, Aero. Engineer, Glenn L. Martin Co.; Julius A. Jaeger, Engineer, Lockheed Aircraft Corp.; R. L. Jahnke, Student, Univ. of Minnesota; A. L. Jarrett, Engineer, Vought-Sikorsky Aircraft Div., United Aircraft Corp.; Ben. J. Kaganov, Engineer, Howard Aircraft Corp.; Donald Kallenbach, Mechanic, United Air Lines Transport Corp.; Robert W. Kamm, Engineer, S. A. Healy Co.; Earl Kastilahn; Gerald G. Kayten, Jr. Meteorologist; L. E. Klar, Engineer, Stinson Aircraft Div., Aviation Mfg. Corp.; R. S. Knecht, Aero. Engineer, Eclipse Aviation Div., Bendix Aviation Corp.; F. G. Kreidler, Exp. Engine Tester, Wright Aeronautical Corp.; A. U. Kutsay, Student, Univ. of Michigan; E. V. Laitone, Jr. Aero. Engineer, N.A.C.A.; Harold R. Larsen, Asst. to Chief Engineer, W. & L. E. Gurley; Sherman H. Lee; Harvey A. Leich, Jr. Engineer, Grumman Aircraft Engineering Corp.; Wm. A. Leuang, Jr. Stress Analyst, Glenn L. Martin Co.; Aaron Levine, Research Asst., Stevens Inst. of Technology; Charles N. Levy, Jr. Aero. Engineer, U.S. Army Air Corps; Charles J. Libby, Research Engineering Asst., Electrical Testing Laboratories; Hans P. Liepmann, Instructor in Aeronautics, Univ. of Cincinnati; Ying Liu; William G. Lothrop, Engineer, Boeing Aircraft Co.; James Louie, Student, Univ. of Washington; Goodwin R. Luck, Aviation Cadet, U.S. Marine Corps Reserve; J. C. Luttrell, Exp. Engine Tester, Wright Aeronautical Corp.; Bernard Lyons, Meteorologist; W. F. Malkiewicz, Stress Analyst, Fairchild Aircraft Corp.; Philip R. Mannick, Draftsman, El Segundo Div., Douglas Aircraft Co.; Paul H. March, Boeing Aircraft Co.; Max W. Martin; James W. McCauley, Jr. Aero. Engineer, U.S. Army Air Corps; J. Lowrie McLarty, Engineer, Fleet Aircraft Co.; Wallace Meins, Draftsman, Lockheed Aircraft Corp.; G. R. Mellinger, Apprentice Engineer, Pan American Airways; William F. Meyer; Philip L. Michel, Engineer, Brewster Aeronautical Corp.; Eugene P. Miller, Draftsman, Vultee Aircraft, Aviation Mfg. Corp.; Bruce Mitchell, Aero. Engineer, El Segundo Div., Douglas Aircraft Co.; E. L. Moore; M. W. Murgittroyd, Chief Receiving Clerk, Boeing Aircraft Co.; Eli S. Newberger, Engineer, Wendt Aircraft Corp.; Gail S. Newsom, Sr. Detail Draftsman, Lockheed Aircraft Corp.; O. F. Olsen, Electrical Engineer, Grumman Aircraft Engineering Corp.; Clayton J. Osterhout, Jr. Aero. Engineer, N.A.C.A.; F. Weston Palmer, Aero. Engineer, Douglas Aircraft Co.; Lt. E. W. Parish, Jr., Naval Aviator, U.S. Navy; William F. Parker, Stress Analyst, Lockheed Aircraft Corp.; C. S. Partisano, Test Engineer, Pratt & Whitney Aircraft, United Aircraft Corp.; C. Desmond Pengelley, Aerodynamicist, St. Louis Airplane Div., Curtiss-Wright Corp.; Fletcher N. Platt, Aero. Engineer, Vought-Sikorsky Aircraft Div., United Aircraft Corp.; Y. P. Poon; Casimer Porowski, Glenn L. Martin Co.; James T. Power, Draftsman, Lockheed Aircraft Corp.; Merritt Preston; Paul E. Purser, Glenn L. Martin Co.; William G. Ramke; Norman W. Reed, Aero. Engineer, Vultee Aircraft, Aviation Mfg. Corp.; Blake Reynolds, Test Engineer, Pratt & Whitney Aircraft, United Aircraft Corp.; W. R. Rhoads, Draftsman, Douglas Aircraft Co.; Arthur Ritter, Engineer, Aircraft Research Corp.; Jere H. Roach, Engineering Dept., Bury Compressor Co.; Joseph I. Robinson, Aero. Engineering, Bell Aircraft Corp.; Fred C. Rosacker, Detail Design, Ryan Aeronautical Co.; Calman Rosenkranz, Aero. Engineer, Republic Aircraft Corp.; R. A. Ross; Richard K. Ruhe, Glenn L. Martin Co.; Howard Russell, Aero. Engineer, El Segundo Div., Douglas Aircraft Co.; Robert Saks, Engineer, Consolidated Aircraft Corp.; Frank B. Sandgren, Instructor in Aero. Engineering, New York Univ.; Paul E. Sandorff, Engineer, Lockheed Aircraft Corp.; Harry S. Scales, Jr. Meteorologist, Transcontinental & Western Air, Inc.; Robert Schairer, Aerodynamicist, Douglas Aircraft Co.; Eugene F. Schmidt, Draftsman, Socony-Vacuum Oil Co.; Robert J. Schoonmaker, Production Dept., Glenn L. Martin Co.; Lt. A. B. Scoles, Naval Aviator, U.S. Navy; W. P. Secord, Draftsman, North American Aviation, Inc.; J. Howard Self, Aero. Engineer, North American Aviation, Inc.; D. H. Shiley; John W. Shorter, Engineer, Waco Aircraft Co.; Manuel Silos, Designer, Pioneer Engineering & Mfg. Co.; R. H. Smith, Student, Mass. Inst. of Technology; W. W. Sohler, Draftsman, American Can Co.; Seymour I. Solomon; I. A. Stanton, III; Louis J. Stary; Geo. P. Stevens, Stress Engineer, Vega Airplane Co.; W. P. Stevens, Jr., Engineer, Lockheed Aircraft Corp.; Wesley A. Steyer, Asst. in Structures, Fleetwings, Inc.; John R. Sutton, Radio Service, Lear Developments, Inc.; Gail H. Swan, Stress Analyst, Fleetwings, Inc.; Brown Thigpen; H. William Thomas, Flying Cadet, U.S. Army Air Corps; D. M. Thompson, Stress Analyst, Fleetwings, Inc.; Ensign R. G. Tills, U.S.N.R.; F. Wallace Tobin, Jr., Jr. Engineer, Edward G. Budd Mfg. Co.; C. J. Towle, Apprentice Engineer, Grumman Aircraft Engineering Corp.; Vernon G. Townsend, Aero. Engineer, Glenn L. Martin Co.; Paul H. Treide, Glenn L. Martin Co.; Joseph R. Trueblood, Jr. Aero. Engineer, U.S. Army Air Corps; Dr. Hsue-shen Tsien, Research Fellow in Aero., Calif. Inst. of Technology; George H. Tweney, Aero. Engineer, Pan American Airways; Kermit E. Van Every, Engineer, Douglas Aircraft Co.; Wesley L. Vaughan, Stress Analyst, Douglas Aircraft Co.; Frank J. Vlcek, Jr. Detailer, Lockheed Aircraft Corp.; John F. 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Youngberg, Draftsman, Lockheed Aircraft Corp.; Shao Wen Yuan, Student, Calif. Inst. of Technology; Pei-Lin Yung, Aero. Officer, National Air Force Academy, China; O. C. Zahnow, Engineer, Glenn L. Martin Co.; William M. Zarkowsky, Grumman Aircraft Engineering Corp.; B. Sherman Zeliff, Instructor, Casey Jones School of Aeronautics; Earl M. Zerbe, Engineer, Bendix Products Corp.

Aeronautical Reviews

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Aerodynamics

Aerodynamic Characteristics of a Wing Profile at a Velocity Near That of Sound. Lt. A. Ferri. Optical experiments throw light on the behavior of the shock wave. It is concluded that the shock wave represents a spasmodic recompression after the expansion which occurs at sonic speed on the upper leading edge. It is initially limited to the small zone where sonic speed has been reached, but it goes on spreading and tilting backwards until it becomes so oblique that divergence of the lines of flow ahead of the shock leads to expansion instead of recompression. As speed increases, divergence of the lines of flow grows less and the two waves merge, forming the "flutter zone."

Experiments were made in the Guidonia supersonic wind tunnel upon a steel wing section of 4-cm. chord and 2.5-mm. thickness, cut from a propeller blade, for Mach numbers of about 1. To minimize difficulties caused by the "layer shift" of air moving at a high speed between rigid walls, the tunnel was built with special modifications, giving a free flow with a rectangular jet section. Experiments were made at Reynolds Numbers ranging from 180,000 up to 250,000, no appreciable variation being apparent in the results. Long abstract. *Aircraft Engineering*, September, 1939, pages 353–354. Complete article. *L'Aerotecnica*, April, 1939, pages 404–425, 16 illus.

The Beating Wings of Pigeons. G. Guidi. Method of obtaining three complementary projections of a pigeon in flight by photographing the same bird in different positions relative to the camera (side view, tail view, and view from above) during successive flights is described in the original article. Very brief abstract. *Aircraft Engineering*, September, 1939, page 353. Complete article. *L'Aerotecnica*, February, 1939, pages 121–132, 14 illus., 1 table.

China's Large Wind Tunnel. F. L. Wattendorf. Tsing Hua 15-ft. wind tunnel having an interchangeable 18-ft. section for full-scale engine and propeller tests was recently erected in Central China. Current aerodynamic and other problems in China which had to be considered in the design of the tunnel are outlined. Airplanes are imported from abroad, are built under license, or are designed and produced independently. Choice of tunnel type and size and aerodynamic design in regard to pressure orifices in the tunnel wall and guide vanes are discussed. Structural design of the tunnel to withstand tropical storms, and test-section arrangement, power plant, and measuring apparatus are described in detail and illustrated. *Aircraft Engineering*, September, 1939, pages 345–348, 350, 12 illus.

Results from the Deutsche Forschungsanstalt fuer Segelflug Smoke Tunnel. A. Lippisch. Paper and discussion by G. T. R. Hill, H. C. H. Townend, W. O. Manning, B. S. Shenstone, Melville Jones, and A. Fage. Preprint abstracted in previous issue. *Jour. Royal Aeronautical Soc.*, September, 1939, pages 653–672, 9 illus.

Aircraft Design

Flying-Boat Entrance Lines. F. W. Lanchester. The punt-like entrance line is taken merely as a basis for the discussion of the design of the entrance lines of a flying-boat hull. It is shown that there is no objection to the horizontal lines being drawn as easy as the designer wishes, as in the lines of an ordinary boat or sea-going vessel, but all vertical section lines must comply with the conditions laid down by the author. A hull is represented diagrammatically in side elevation and it is shown that when the hull encounters a steep wave front, the reaction is at right angles to the entrance line. If the entrance line has too great an inclination, the wave tends unduly to throw up the nose of the boat and to cause it to porpoise, and in its subsequent descent the boat may strike the water at a dangerous angle. Surface of another boat shown is more nearly vertical so that all forces acting on the surface pass near the center of gravity. *Engineering*, September 15, 1939, pages 298–299, 4 illus.

A New Idea for Flying-Boats. Dornier proposal is for a high monoplane wing curved down at a sharp dihedral angle on each side of the hull to meet the water level from which it rises again with a sharp dihedral to keep the wing tips well clear of the water. It is claimed that drag is cut down, that the whole structure of the wing is lifted usefully, and that all tendency to roll is eliminated. Parts of the wing which may come in contact with the water can be made proof against the action of the water shock. Designs for an amphibian flying boat are also included in the specification. Discussion of British patent No. 499,069. *Aeroplane*, September 21, 1939, page 370, 2 illus.

Surface Finish and Performance. A. D. Young. Antipathetic problems of aerodynamic refinement and practical construction. Main characteristics of boundary layer flow are briefly outlined and the right order of excrescences on the surfaces so as not to disturb the laminar layer is considered. Drag of a roughened surface is dealt with, and the effects on drag of isolated surface irregularities and protuberances such as flush rivets, rivets, and lap joints are pointed out. Formulas for estimating the drag of rivet heads and rearward-facing lap joints are derived. Effects of surface roughness on the maximum lift are taken up. Some American test results on the effects of leading-edge protuberances are quoted, indicating that the onset of the stall is very sensitive to the state of the surface at and near the leading edge on the upper surface. Evidence of the effect of paint on the surface is given. *Aircraft Engineering*, September, 1939, pages 339–341, 350, 6 illus., 10 equations.

Surface Roughness and Wing Drag. M. J. Hood. N.A.C.A. test results on the effects of some common surface irregularities on wing drag, including brazier-head and countersunk rivets, lapped sheet-metal joints, manufacturing irregularities, surface roughness, and paint. Paper presented before the Society of Automotive Engineers. Preprint abstracted in previous issue. *Aircraft Engineering*, September, 1939, pages 342–344, 8 illus.

Aerodynamic Figures of Merit—Drag and Reynolds Number. W. R. Andrews. Pitfalls in the estimation of airplane drag on the skin-friction basis are pointed out, particularly that inferred by the existing Figure of Merit that the drag falls with increasing Reynolds Number, in the same ratio as the theoretical skin-friction curve. Actually, for a streamlined body (or wing) the drag curve remains practically parallel to the theoretical one. By definition the body considered represents the practical idea, and as such should have a constant Figure of Merit invariable with Reynolds Number, a condition not satisfied by existing methods.

Unless it is possible to make comparisons between results at different Reynolds Numbers, the Figure of Merit becomes a number without significance except when associated with the appropriate Reynolds Number. One of the two methods discussed is to assume the parasitic skin-friction drag equal to the theoretical skin-friction drag plus the coefficient which is practically constant at all values of Reynolds Number (even to rough bodies) and to correct all results to a Reynolds Number equal to 107 when theoretical skin-friction drag coefficient equals 0.003. The other method is to take the sum of the parasitic skin-friction drag coefficient plus the difference directly as a basis of comparison. Precautions in making comparisons by either method are pointed out, and conclusions are reached as to how much of the losses associated with propeller and slipstream should be debited to the account of drag. *Flight, Aircraft Engr. Sup.*, August 3, 1939, pages 29–33, 14 illus., 5 tables., 8 equations.

Aerodynamics of the Rotary Wings with Blade Angle Control. A. Pflueger. In the rotary-wing system calculated a change of angle of attack of the rotors, in such a way that the torsional angle of the blade profile is variable linearly with the flapping angle of the blade, is possible. The method developed by Wheatley for calculation of the air forces of rotary-wing aircraft is extended in such a way that, in place of constant blade angle, the calculation is based upon a linear dependence between blade angle and flapping angle. Application of the formulas developed to a rotor of normal size with a blade-angle control shows that no peculiarity whatever in the behavior of the aircraft in hovering flight occurs. Report of the Focke-Wulf Aircraft Company. *Luftfahrtforschung*, July 20, 1939, pages 355–361, 9 illus.

Determination of Circulation Distribution for the Two-Dimensional Wing in any Periodical Motion. K. Jaeckel. By introduction of a function derived from the function of the vortex distribution, it was found possible to express simply the velocity produced by all the vortices at the profile, and thereby to determine the circulation distribution, coefficients of which may be obtained if the solution of a new type of integral differential equation may be assumed to be known. Solution may be obtained according to a periodic time law so that, for this most important case, the result is given which, as a special case, comprises the final formulas by Kuessner. Brief abstract. *Aircraft Engineering*, August, 1939, page 315. Complete article. *Luftfahrtforschung*, March 20, 1939, pages 135–138, 33 equations.

The Future of Flying. H. E. Wimperis. Speed, size, and range of aircraft of the future are considered. Limitations of engine power on size and of wing loading on speeds are discussed. The author points out that in the case of military types having top speeds of 550 m.p.h. or thereabouts, landing speed could hardly be less than 150, giving a wing loading of 100 lb./sq.ft. It looks as though wing loadings for civil types will go little beyond what is now planned, but in the case of military types, present-day figures may certainly be doubled unless some new wing arrangement can be discovered that will greatly reduce the loading figure when a landing is about to take place. While speeds of military aircraft are now in excess of 400 m.p.h. and will rise still higher, civil aircraft rarely go faster than 250 m.p.h. and there is doubt whether even so high a speed as that is economically advantageous. Some new developments in flying boats of today (which represent a great technical advance in quality, but not any marked advance in size), some important problems in aeronautics which are being investigated, and other problems arising with their solution are mentioned briefly. Abstract British Association paper, *Aeroplane*, September 7, 1939, pages 310–313, 4 illus. *Engineering*, September 8, 1939, pages 278–280. First part of the complete paper. *Engineer*, September 8, 1939 pages 254–256.

Lift Distribution and Derived Sizes for Wing in Weak Inhomogeneous Flows. K. Bausch. On the basis of the Prandtl theory of the "carrying line," calculation of lift distribution of an airfoil in a stationary airstream which is parallel to the symmetrical plane of the airfoil and which varies little in velocity and direction from place to place, is reduced to the solution of the same problem in an homogeneous flow by adopting suitable variation of incidence along the span. Results are applied to the determination of correction factors for measurements on wings in wind tunnels necessitated by small local fluctuations in direction and velocity of flow, as well as to the calculation of rolling moments, induced drag, and turning moments of a wing rotating with constant velocity in a uniform airstream about the flow axis. Short abstract of D.V.L. report. *Aircraft Engineering*, August, 1939, page 315. Complete article. *Luftfahrtforschung*, March 20, 1939, pages 129–134, 5 illus., 3 tables, 39 equations.

The Light Aeroplane of To-Morrow. J. P. Smith. In the ideal layout suggested controls would be conventional, with rudder and front wheel connected to the rudder bar and brakes on the rear wheels. Eventually, the front wheel would be connected to the control wheel operating the ailerons, and twin fins and rudders would probably be fitted. Twin rudders might then be interconnected with the ailerons and front wheel or abolished altogether. Engine would be controlled by a foot or hand throttle—the foot throttle for use on the ground, and the hand throttle for take-off and while in the air. Brakes would be controlled by a foot pedal and flaps by a hand lever. A geared engine would be used with a controllable-pitch propeller. Requirements for aerobatics, design conditions, load factors, and materials are discussed and reference is made to American requirements for light airplanes and to types of American airplanes. *Flight*, September 7, 1939, pages 215–217, 3 illus.

The Modern Twin-Fin Tail. B. S. Shenstone. From the point of view of tailplane efficiency it does not matter whether the fins are on top of, below, or symmetrically disposed with respect to the tailplane. As far as side loads with neutral rudders are concerned, it is best to use symmetrically-disposed fins. Basic data are given on the effects of the endplate fins (fins plus rudders) on the tailplane (tailplane plus elevator) as considered from the viewpoints of increase of aspect ratio and increase of area. Results of an analysis made at Goettingen are discussed in detail. *Aircraft Engineering*, August, 1939, pages 311–313, 10 illus.

Momentum Theory of Induced Drag. J. L. Taylor. The classical Lanchester-Prandtl theory of induced drag involves consideration of the velocity field of the trailing vortices, which, to the non-mathematical, may be something of a stumbling block. It is shown that on a certain assumption the main results of the vortex theory for the common case of a monoplane wing

with approximately elliptic distribution of lift along the span may be derived from simple considerations of momentum and energy of the air. There is an obvious analogy in the momentum or Glauert theory of propellers. It is assumed that in the induced drag and induced angle of incidence, the influence of the wing can be regarded as being confined to a limited volume of air in its vicinity. Brief note. *Flight, Aircraft Engr. Sup.*, August 3, 1939, page 34.

Production Float Design. J. G. Shonts. Method of designing a relatively complex structure, such as an aircraft float, so that it could be constructed on a modern production basis, utilizing the hydraulic press and drop hammer for 90 percent of its major structural parts. Basically, the float structure described consisted of two main watertight fore-and-aft strut-attachment bulkheads, intermediate floor frames, side frames and crown arches, bow and stern frames, and the side and crown longerons. A typical transverse frame assembly incorporated a floor frame, side frame, and crown arch, these parts being formed as a single-stage stamping in the hydraulic press. *Aero Digest*, September, 1939, pages 42–43, 6 illus.

Stress Analysis and Structures

The Analysis of Leading-Edge Wing Beams. J. S. Newell. Paper previously abstracted from preprint. *S.A.E. Jour. (Trans.)*, September, 1939, pages 385–388, 3 illus., 3 tables, 13 equations.

The Force Introduced on Monospar Wing Structures by Incompletely Formed Bulkheads. F. Reinitzhuber. Force distribution resulting from the force introduced by incompletely formed bulkheads in monospar wings, can be determined by means of the shearing field diagram from a statically indeterminate calculation. A numerical investigation is given for force distribution of a wing having two adjacent engine bulkheads stressed by torsional moments and incompletely constructed since in half of the wing cross-section the stiffening plate is lacking. Regardless of incomplete bulkheads, an extensive distribution of introduced forces over the entire wing cross-section is obtained, which depends largely on the stiffness of bulkheads, in particular of the flanges in the rear portion of the tubes, and on the nature of the forces introduced in the bulkhead.

By simplified assumptions it is possible to reduce the number of static redundants, and thus the mathematical procedure, except that considerable distortion of the force diagram is involved thereby. When in the two incompletely developed engine bulkheads two equally large torsional moments in the same direction are introduced, a simple statically indeterminate calculation is sufficient to obtain a useful approximate value for the moment portion of the rear tubes. Report of the Henschel Aircraft Company. *Luftfahrtforschung*, July 20, 1939, pages 349–354, 7 illus., 6 tables.

Simplifying Stress Analysis. F. R. Shanley. Application of modern stress-analysis methods to practical problems are discussed, including: use of the arbitrary load axis; transfer of external loads to shear center; dihedral and sweepback effects; chord coefficients; shear flow; box-beam analysis; and a simplification of single-cell analysis methods by combining the load-axis method with that of "cutting" the cell. *Aviation*, August, 1939, pages 32–33, 47, 82, 4 illus., 1 table, 4 equations.

Solution of Simultaneous Equations. E. J. Richards. Most simultaneous equations obtained in stress work are those used for solving for the redundancies when the method of strain-energy is used. Method described is for the most part identical with that used at present. It serves as a good method of checking at a fairly early stage, and the amount of work is reduced to half. Method is only of use when the number of cases to be examined warrants it. Redundancies equations are all obtained from differentiation of the same expression, and the matrix formed by writing down the coefficients in a block is symmetrical. Once a block has been solved, as many cases can be considered as is necessary, without more work. *Flight, Aircraft Engr. Sup.*, August 31, 1939, page 37, equations.

Stiffness of Beams and Cables. H. Yushan. By comparison of the maximum bending moment and maximum deflection, the effect of variation of stiffness on the transition of a laterally-loaded member with tensile end load from a "beam" to a "cable" is calculated. Formulas are developed for the flat beam tie under uniformly distributed load and under concentrated load, respectively, and for the effect of initial curvature. A non-dimensional stiffness constant is introduced and some criteria are given for practical application. *Aircraft Engineering*, August, 1939, page 314, 2 illus., 16 equations.

Structural Considerations Favoring Plastics in Aircraft Structures. C. F. Marschner, Glenn L. Martin Company. Load-carrying efficiency for equal weights and, for equal load-carrying ability, both weight efficiency and minimum weight are compared for stainless steel, magnesium alloys and spruce, based on dural = 100, in a table giving axial and bending deflection, local instability, plate rigidity, torsional deflection of monocoque shells, and shear deflection in stable webs and thick-walled tubes. Eight conditions governing design are given, including: axial, bending and torsional deflections, local instability, and plate rigidity.

From structural design formulas, curves are derived showing: minimum moduli required to give equal load-carrying ability or equal deflections for the same weight of structure, similarly stiffened and critical in the same loading conditions as the equivalent aluminum structure, and the peculiar correlation between strength and weight throughout a wide range of specific gravity.

Assuming that a material having certain properties specified has been developed, and that the structure is to be redesigned to take full advantage of the lower specific gravity of the material, the author shows the weight efficiency, and the load-carrying efficiency from the standpoint of plate rigidity and torsional rigidity, and thus the possibilities inherent in light materials. *Modern Plastics*, September, 1939, pages 41–42, 44, 68, 70, 3 illus., 3 tables, equations.

Transfer of End Load in Stringers. E. J. Richards. A general solution is obtained for diffusion of stress in n equal and equally spaced stringers in a stiffened panel subject to any boundary conditions at the ends of the stringers and is applied to determining the stress distribution in a panel such as that obtained in the airfoil between the spars. A formula is derived which gives the distance in which the stringers pick up their full load. Problem of bending of a fuselage with a symmetrical hole in it is dealt with by this method. Good agreement with the method at present in use is found and the necessity for guessing the distance in which the effect of the hole dies out is thus eliminated. The simple approximate formula given for this distance agrees fairly well with that taken in actual practice. Distance in which longerons pick up their full loads is examined and an approximate formula obtained. *Aircraft Engineering*, August, 1939, pages 301–305, 10 illus., many equations.

Composite Construction. J. Coustolle. Sheets of plywood which will form the outer covering of the upper surface of the wing are placed in a mold and assembled with Certus glue. The spars have flanges which are glued to the covering. Flanges consist of battens of spruce 10-mm. square and are also glued to each other. As the wing root is approached the number of battens is increased, there being 20 to each flange in the wing discussed. Other battens placed transversely to act as ribs are glued to the plywood covering. Lower flanges of the spars and spruce strips which serve as lower flanges of the ribs are glued on, and the structure is completed by gluing on the lower surface over the spars.

Technical, constructional, cost, military, and special advantages are also discussed. Method can be applied in all instances and to all component structures of the airplane—wings, ailerons, fuselage, and tail units. Object is to reduce to a minimum the work of construction, cost of maintenance, and price of raw material. Long abstract. *Aeroplane*, September 21, 1939, pages 367–369, 4 illus. Complete article. *L'Aéronautique*, August, 1939, pages 299–302, 5 illus.

Investigations on Vibrations in Flight (Wing Vibrations Produced by a Vertical Gust). C. Minelli and V. Grobner. Constants are tabulated (in the original article) for a tapered wing of variable flexural rigidity fixed at the root and immersed in a uniform horizontal current, then suddenly subjected to a vertical up-gust which gradually dies away. Similar calculations are applied to a rectangular wing flying horizontally which is struck by a damped vertical up-gust. Four graphs (in the original article) show the dynamic displacement of the wing tip as a function of time. Dynamic stresses produced by an up-gust seem to be diminished by removing loads from the fuselage and transferring them to the wings. Stresses produced by an up-gust are attenuated if the wing is tapered. Stresses are also diminished if the wing is extremely stiff against bending, and if the stiffness is continued as far as the wing tip. Given equal initial speed, fluctuations in intensity of the up-gust do not seem to affect the stresses noticeably. The faster the airplane, the more effective is the damping out of vibrations produced by an up-gust, but the corresponding maximum dynamic stresses are increased. Long abstract. *Aircraft Engineering*, September, 1939, page 354. Complete article. *L'Aerotecnica*, April, 1939, pages 373–403, 6 illus., many tables and equations.

Monocoque Stability in Compression. J. L. Taylor. In certain expressions previously given by the author for the stable loads which a curved stiffened-skin panel was capable of carrying without collapse by buckling, it was assumed that waving over relatively long lengths was impossible, because of the presence of rigid bulkheads or similar supports at intervals. While this will normally be the case in practice, it may happen that in some part of the structure a long length of panel remains without support other than that given to it by the ordinary frames and stringers. As this will tend to reduce the buckling load, the theory previously given is completed to include the case of buckling in long waves. *Aircraft Engineering*, September, 1939, pages 349–350, 4 equations.

On Quality versus Quantity Production. C. G. Grey. "But making Rolls-Royces of the air to be destroyed by the thousand in time of war and by the hundred in time of peace is just as idiotic. . . . . if timber, steel-tube, and fabric aeroplanes will do pretty nearly as well, all the extra elaboration of an all-metal airplane is not worth while unless it can do better." Mr. Grey's arguments for simplification of design and for adoption of steel-tube, timber and fabric construction to speed up production and to cut down man hours are presented. *Aeroplane*, September 14, 1939, pages 331–332, 2 illus.

Torsion of Hollow Rectangular Prisms with Thin Walls (Function of the Diaphragms and of End Bands Acting Also in an Axial Direction). C. Minelli and Tullio Viola. A hollow thin-walled rectangular prism with diaphragms is taken, the end sections being free to bulge, and a twisting moment is applied in such a way that $r\delta$ = constant. State of tension and of displacement produced will be what might be anticipated from Bredt's theory, according to which the sections bulge but remain rectangular. It is easily seen that the diaphragms are not stressed. By taking a prism of the same type, but without partitions and with one end fixed so as to prevent the corresponding section from bulging, similar stresses will produce the same state of tension (the normal longitudinal tension will be absent), but a different state of displacement, since the sections will become parallelograms but will remain flat. Lack of normal tensions throughout, and particularly in the section with fixed end, shows that there are no axial stresses. Short abstract. *Aircraft Engineering*, September, 1939, page 353. Complete article. *L'Aerotecnica*, March, 1939, pages 273–292, 6 illus., 27 equations.

Aircraft Accessories

Standardized Control Rods. Junkers method of reducing the number of parts in control riggings is illustrated in a description of the standard control rods, levers, shafts, bearing brackets, and feet. Controls used on the Junkers Ju 90 airplane are referred to. Demands for standardized rigging were chiefly made by the German Air Force, since interchangeability of parts is factor of primary importance to ensure simplification of supply services and ease of maintenance of the first-line fleet. Reprinted from Junkers-Nachrichten, April. *Aircraft Engineering*, September, 1939, pages 362–363, 8 illus.

Hydraulic Selector Valve. In the Aircraft Accessories No. 62008 hydraulic selector valve, a variable-flow governor controls the volume of oil delivered to each end of the actuating cylinder for controlling the extension and retraction time of the flaps, and a pressure governor returns the excess fluid to the fluid reservoir through the pressure-control valves also serving as a protection against excessive air speeds. At any speed in excess of the design load of the ship the pressure governor allows the fluid to return to the reservoir and the flaps remain closed until the speed of the airplane is lowered to the safe load of flaps. Brief note. *Aero Digest*, September, 1939, page 156, 1 illus.

Natural Dual. Simple arrangment designed by W. E. Gray with the object of preserving normal control movement with a central control column in side-by-side-seater airplanes. Due to a parallel linkage in the vertical column, the cross remains horizontal, and a similar arrangement in the cross tube keeps the motions of the hand grip parallel with those of the vertical column. Full aileron movement when the stick is back is also assured. Drawing only. *Flight*, August 3, 1939, 1 illus.

Tail Wheel Brake for Light Aircraft. Aeronautical Trading steerable tail wheel with brake assembly can be installed on light aircraft such as the Cub, Aeronca, Taylorcraft, Rearwin, Porterfield, Fleet, and others. New Departure brake incorporated in the assembly is operated by a lever installed in the cockpit. Firestone 6 × 12 cushion-center solid-rubber tire is used. Brief reference. *Aero Digest*, September, 1939, page 156, 1 illus.

Aircraft Assisted Take-Off

Atlantic Services. Major R. H. Mayo. Factors of wind and time affecting the services across the Atlantic are considered, and the necessity for help at take-off for these aircraft is pointed out. Advantages of the composite-aircraft scheme of assisted take-off as applied to commercial aviation are discussed. Abstract from British Association paper. *Aeroplane*, September 7, 1939, pages 305–307, 3 illus.

Technical Notes. Tests have been made in Germany with an airplane of 600 kg. and 20-square meters surface descending a ramp of 35°. It was proved that the length of rolling before take-off was only a third of that necessary for take-off from level ground. Brief reference only. *Les Ailes*, August 28, 1939, page 8.

Aircraft Maintenance

The Repair and Maintenance of Light Metal-Aircraft. J. G. Rising. Methods employed in the maintenance of Luscombe 50 and 65 airplanes, are briefly discussed with a few details of the structure of these airplanes. *Aero Digest*, September, 1939, page 63.

Aircraft Manufacture

Large Flying-Boats in Series. Methods by which large civil and military flying boats are built in the Rochester plant of Short Brothers, Ltd. Planning system is considered and a production chart is illustrated. Methods of producing the main plane, spar assembly, final assembly, main plane assembly, hull, tail surfaces, controls, major subassemblies, wing-tip floats, ribs and leading edge sections, and final erection are described in great detail with many illustrations of parts of the aircraft structure and of jigs and fixtures used in the construction. Production methods include those for both the Sunderland and the new G-class Empire flying boats. *Aircraft Engineering*, August, 1939, pages 319–331, 37 illus.

Methods of Clamping Sheet Metal for Riveting. C. H. Plock. Types of nut and bolt used for clamping, riveting clamps with hooks, French and German examples of riveting clamps with sliding wedges, Myers riveting clamp, riveting clamps with split taper-pin legs, and a special type of pliers designed for inserting the clamps are illustrated and described. From *Luftwissen*, May, 1939. *Aircraft Engineering*, August, 1939, pages 317–318, 7 illus.

Vultee's Special Machines. D. I. Carroll. Machines specially designed by the Vultee Aircraft Division for increasing aircraft production and operations undertaken with them are described, particularly in the application of production methods to the entire drop-hammer process, and use of profiling machinery. Profiling a gun-ring mount and the long aluminum-alloy gusset plate used to help tie the wing rear beam to the trailing-edge ribs and surface sheet material are discussed. *Aviation*, August, 1939, pages 30–31, 78, 4 illus.

For Medium Production. German Obo compressed and laminated wood has been used extensively in aircraft production in forming dies for shaping metal sheets with thickness up to 1.5 mm. Material is also suitable for dies used in shaping heated metal such as magnesium-alloy sheets heated to 300°C., and for impact shaping work on a drop hammer, as distinct from ordinary press work. Properties are given. *Aircraft Engineering*, September, 1939, page 365.

Problems of Production in Large Series. P. Leglise. Five studies concerning series production of aircraft are recommended, including: decentralization of the production of elementary parts; the airplane designed strictly in view of series production; adaptation and modification of a given technique to facilitate construction in series; construction in series of an airplane designed directly for the series; machines in production in large series; and variation of cost in function of the quantities of the airplanes constructed.

Opinions of T. P. Wright of the Curtiss-Wright Company and of Sydney Camm, chief engineer and director of the Hawker Aircraft Company, in regard to design of aircraft for series production and standardization of parts are quoted. Opinions of L. Coroller are presented regarding the point to which it is desirable to decentralize the factories from the shops working on parts, and the airplane designed strictly for series production. Observations on series production of airplanes and suggestions for accelerating production are included. *L'Aéronautique*, July, 1939, pages 258–263, 265–267, 7 illus.

Aircraft for High-Altitude Flight

Observations on Flight at High Altitudes. G. Getzlaff. Possibilities of altitude flying, and its advantages compared with flight near the ground. Discussion covers: purpose; additional expenditure involved; precautions to be taken for the human organism; improvement needed in power plant conditions; cooling problems; instruments and propeller requirements; and problem of control. Table gives altidude, crew, passengers, and in some cases range and high altitude accessories for the Curtiss (two 1400-hp. Wright Cyclone engines), Lockheed 22, Renard R.35, Douglas DC-4, Boeing YB-17A, Boeing 307 "Stratoliner," Centre 2234, and aircraft specifications of TWA and Pan American Airways. *Luftwissen*, June, 1939, pages 197–203, 7 illus.

Aircraft, Manually Driven

Flight with the Lowest Power as a Tendency Towards Man-Powered Flight. R. Chiappulini. Power required for the normal airplane with rigid wings and tractor propeller, for the oscillating airfoil mechanism, and for the rotary-wing aircraft is calculated, and problems of man-powered flight are considered. It is shown that an airplane of equal weight and similar aerodynamic qualities needs less power for horizontal flight than a helicopter, and that, of the three, the helicopter is less suitable for human flight. Mechanics of muscular action, as contrasted with mechanical motion, are dealt with. Sketches (in the original article) show possible devices for man-powered flight one of which has already been tried out in Russia. Short abstract. *Aircraft Engineering*, September, 1939, page 353. Complete article. *L'Aerotecnica*, February, 1939, pages 133–177, 27 illus., 3 tables, many equations.

Aircraft Performance

Making Use of Ground Effect. A. H. Blaisdell. Use of ground effect by the pilot in the landing of airplanes. Ground effect comes into the picture during the interval between level-off and contact when the airplane floats or skims along quite close to the landing surface. Length of the "float" depends on the time required for the drag to absorb the excess of kinetic energy possessed by the airplane over and above that which it possesses under stalled flight. The fact that ground effect tends to produce a higher lift for a given angle of attack, means that the pilot cannot bring the angle of attack as quickly to its stall value, and this factor contributes to producing the "float." Physical characteristics of ground effect and its magnitude discussed. *Aviation*, September, 1939, pages 32–33, 77–78, 5 illus., 3 equations.

Climb Performance in Airplane Towing. W. Pfeiffer. Method for computing rate of climb of a power-driven airplane with a motorless glider attached. Calculating procedure is simplified in that, in addition to the weights, it requires only a few numerical values pertaining to aerodynamic conditions and the value of the rate of climb of the power-driven airplane without the attached glider, as the only quantity depending on engine power and propeller efficiency. *Luftwissen*, June, 1939, pages 205–206, 2 illus., 7 equations.

Investigations on the Safety of the Take-Off of Aeroplanes in Connection with the Qualities of the Aeroplane, 1938. A. G. von Baumhauer and P. De Winter. Analytical consideration of safety in take-off, which may be used as a practical guide for predetermination of a safe take-off policy, and a means whereby dimensions of an airport, such as shall meet rational requirements for a safe take-off of a definite airplane type, can be determined. For assessment of "safe" take-off, a method of consideration has been adopted which is comparable with the detailed analysis applied in assessment of safety of a structural component in strength specifications.

In order to obtain data necessary to enable assessment of take-off qualities, it has been usual practice to correct an arbitrary take-off to normal conditions with regard to ground and atmosphere, but arbitrary choice in the take-off policy adopted by the pilot has not been eliminated. The C.K.L. diagram developed eliminates this arbitrary choice, and can be used equally well for determination of take-off path when a prescribed climbing policy is followed. This is done by the graphical method which is described and by means of which the computations are rendered accessible to the draftsman. Translation of report of the Dutch Commission for Investigation of Aircraft Material. *Jour. Royal Aeronautical Soc.*, September, 1939, pages 673–714, 22 illus., 6 tables, 25 equations.

Aircraft Propulsion by Reaction

Reaction as a Means of Auxiliary Propulsion. Z. Leliwa-Krzywoblocki. By use of auxiliary reaction devices on aircraft, the author believes a decrease of 50 percent in the time for take-off could be obtained. Gunpowder rockets are discussed, and results obtained in experimental flights of the "Storch" glider propelled by this type of rocket are quoted. Reference is made to a Dornier patent for mounting rockets in floats. A table shows theoretical results which could be obtained by the use of rockets of black powder in take-off or climb to a given altitude as applied to motored gliders, line and combat airplanes, pursuit airplanes, heavy bombers, and the R.W.D.5 (powerfully supercharged in view of a flight over a long distance) which Col. Skarzyniski used in his record flight over the Atlantic.

Rockets employing liquid fuel are classified and opinions of E. Saenger are quoted regarding auxiliary propulsion for bombers and transports as well as for flying boats, for take-off with an overload, and for pursuit airplanes during climb to a certain altitude. His calculations for the pursuit airplane are given by which take-off is decreased by 50 percent and climb to 6000 meters is reduced to 1 m. 30 sec. *L'Aéronautique*, July, 1939, pages 276–280, 2 tables.

Aircraft

FRANCE

Caudron C-371 Pursuit. New French Caudron "Cyclone" single-seater low-wing pursuit monoplane appears to have excellent qualities as a fighting machine as well as a trainer for pursuit pilots. Its all-wood structure has been designed for economical volume production, and for low-cost maintenance and operation. Airplane is able to carry two cannons or four machine guns mounted in the wing and firing outside of the propeller disc. Renault 12-cylinder inverted air-cooled 450-hp. engine. Wing span 29.1 ft. Useful load 752 lb. Maximum speed 302.6 m.p.h. at 13,124 ft. Description. *Aero Digest*, September, 1939, page 66, 3 illus.

The French Air Force To-day. P. E. Lamarche. Past and present position of the French aircraft industry and Plan V, as well as organization of the French Air Force, and details of its aircraft are discussed. Plan V calls for the building of 5000 first-line aircraft, including reserves, and 12,000 engines, the first stage to be completed by the spring of 1939 and the second by 1940. Plan called for 200 machines per month as from the spring of this year and that goal has certainly been reached and passed. Expenditures for aircraft which will be required for the new program are compared with those of the past.

Armament, speed, and engines of the aircraft of which the squadrons are composed are given. *Aeroplane*, September 7, 1939, pages 301–303, 4 illus.

How Rossi and Esmond Raised the Speed Record over 10,000 Km. Major M. Rossi and Adjutant Esmond in the Amiot 370 "Anne-Marie" airplane raised the speed record from 236 km./hr. to more than 311 km./hr. over a 10,000-km. course on August 15. The Amiot 370 (two Hispano-Suiza 12-Y 960-hp. engines) weighed about 11 tons at take-off, carrying 7670 liters of gasoline and 320 liters of oil. Account of flight, and details of the Amiot 370 from which the two-engine bombers have been directly derived. *Les Ailes*, August 24, 1939, page 5, 1 illus.

GERMANY

For Peace or War. Germany's biggest aeroplane, the Junkers Ju.90. First experimental airplane (liquid-cooled engines, topspeed 280 m.p.h.) broke in the air during vibration tests. The production airplane used by Luft Hansa carries 40 passengers and has four B.M.W. 830-hp. radial engines and speed of 220 m.p.h. Photographs of both. *Aeroplane*, August 30, 1939, page 267, 2 illus.

Aeroplanes of the Luftwaffe. Messerschmidt, Me.110, latest two-seater fighter (two Daimler-Benz D.B.601 1100-hp. inverted-vee engines, maximum speed 385 m.p.h. at 15,000 ft.) was designed to escort formations of bombers on long raids. Armament is believed to be two 20-mm. cannon fixed to fire forward through the nose, two machine guns fixed in the wings, and a third on a movable mounting operated by the aft gunner.

Latest and fastest bomber in production is the Junkers Ju.88 (two Junkers Juno 211 gasoline-injection 1100-hp. engines, maximum speed 320 m.p.h. at 15,000 ft., range approximately 1800 miles with 4410 lb. bombs and cruising at 250 m.p.h.). Armament is believed to be two shell-firing guns in the nose and large-bore machine guns on top of and below the fuselage behind the wings.

These aircraft and their armament as well as others are described briefly. *Aeroplane*, September 21, 1939, pages 371–375, 11 illus.

A German Long-Range Flying-Boat. In the Dornier Do.26 flying boat, bending down of the main-plane center section to pass into the hull, the adoption of retractable wing-tip floats in place of characteristic sponsons, and pivoting of the rear engines to give clearance from spray are departures from the usual Dornier practice. Flying boat is built specially for catapult take-off, and is the latest Dornier seaplane to be put into service on the South Atlantic route. Flaps are of the slit type instead of being slotted, and ailerons are of the Frise type. Very long description of the construction, and photographs of the structure in various stages of production, and of the

instrument-board and other interior views. *Aircraft Engineering*, September, 1939, pages 357–361, 13 illus.

Machines of the Luftwaffe. Germany appears to favor the high-speed twin-engine lightly-armed bomber as typified by the Heinkels (He.111 and its derivative types), the Dornier Do.17 and the Do.215 developed from it, and the new Junkers Ju.88. The Messerschmidt Bf.110 fighter-bomber is already in service in considerable numbers. Single-seater fighters include the Heinkel He.112 and Messerschmidt Bf.109 which are not identical with the machines used to break the world's speed record. For specialized dive-bombing the standard type is the Junkers Ju.87 which has special flaps to limit diving speed. Adaptations of high-speed twin-engine bombers are employed for strategical reconnaissance, and the Henschel Hs.123 is used for artillery spotting and general observation. Short notes on these types of aircraft and on those used for training, coastal and overseas work, and aircraft carriers. Seventeen recognition drawings of aircraft of the Luftwaffe, prepared to a uniform scale and perspective, are illustrated with details of distinguishing features of each aircraft. *Flight*, September 14, 1939, pages 242a–242d, 19 illus.

Those Heinkel Bombers. H. F. King. The newer short-nosed He-111 bomber differs from the long-nosed type in the greater transparency of the nose and in the upper and lower gun positions, the lower being a permanent well-faired position in place of the retractable gun dustbin. There is no break in the fuselage lines for the pilot's windscreen and the top line is preserved as far forward as the nose gun mounting. Power plants are commonly the latest type of D.B.601 or the Junkers Jumo 211 direct-injection engines with powers ranging up to 1200 hp. maximum.

Heinkel He-118 for dive bombing and ground attack, when fitted with a D.B.600 engine, is said to be capable of about 250 m.p.h. and to have a range of over 870 miles. For dive bombing it has fittings for a 1100-lb. projectile. For attack work it carries four machine guns fixed in the wing, a free gun in the rear cockpit, and a normal bomb load comprising 20 fragmentation bombs of 20–22 lb. each. Descriptions of these aircraft and specifications and performances of the Heinkel 111K bomber.

Drawings show the D.B.601 engine installation in a recent airplane, the appearance of a Jumo 211 nacelle, nose and engine installation of the earlier type of He-111s (D.B.600 engines), and details of the latest type of He-111 bomber. Photographs illustrate the nose-gun mounting of the latest type, the gun being "belt-fed from a peculiar magazine which saddles the breech portion." *Flight*, September 21, 1939, pages 256a–256d, 10 illus., 1 table.

GREAT BRITAIN

Empire Defence. New Saunders-Roe Lerwick long-range flying boat (two Bristol Hercules engines) will be used for oversea reconnaissance, patrol, and bombing. "The Lerwick is amongst the fastest flying boats in the world and is exceptionally well defended." Photographs of the Lerwick and of the Potez 63 multipurpose airplane pointing out the fairings of the latter for the 20-mm. Hispano shell guns. *Flight*, September 7, 1939, pages 228–229, 2 illus.

A Minority Report. Comments on the flight performance of the De Havilland Moth Minor airplane. *Aeroplane*, August 30, 1939, pages 290–291, 1 illus. Comments on performance, and drawing of the control and instrument layout of the Moth Minor as equipped for blind-flying training. *Flight*, August 31, 1939, pages 202a–202c, 4 illus.

Much in Miniature. Design and flight impressions of the British-built Taylorcraft. Long description. *Flight*, August 3, 1939, pages 114–116, 6 illus., 1 table.

To-day's Light Aeroplanes. Characteristics and performances are given for a number of British light aircraft including: the Arpin tricycle pusher; Chilton single-seater; De Havilland Moth Minor and Tiger Moth; G. A. Cygnet; Hillson Helvellyn trainer; Luton Major; Miles Magister; Millichamp pusher; Mosscraft trainer; Parnall 382 elementary and special-purpose trainer; Percival Proctor three-seater Service airplane for deck landing, training and communication work, the Q.6 twin-engined airplane for fast feeder work, and the Mew Gull for fighter training, fast mail carrying and racing; Taylorcraft Plus; Tipsy trainer; and Wicko trainer. General arrangement drawings are given for ten of the best known trainers and touring types and for the two-seater Chilton, the Hillson Helvellyn, and Arpin which are not yet in production. Photographs are also given.

Second article deals with American light airplanes on the British market.

A preceding article entitled "The Light Aeroplane of To-Morrow," by J. P. Smith, discusses future designs. *Flight*, September 7, 1939, pages 218–226, 215–217, 44 illus.

ITALY

Ernesto Breda 65 Attack Airplane. A Frachet. Breda 65 airplane is the equipment of the majority of the attack formations of the Italian Air Force and has been specially designed for bombardment and machine gunning the ground in low flight. It is an all-metal monoplane of mixed construction of steel tubes and duralumin. Powered by a Piaggio P-IX C-40 1000-hp. engine, the airplane has a maximum speed of 460 km./hr. at 4000 meters and climbs to 6000 meters in 11 min. 30 sec. Range 1000 km. with a 550-kg. bomb load, and 1400 km. for reconnaissance. Long description. *Les Ailes*, August 31, 1939, page 9, 3 illus., 2 tables.

Nardi FN 310 Sport Airplane. Low-wing four-seater sport monoplane with dual controls. Powered with a Fiat A.70-S 200-hp. radial engine, the airplane has a top speed of 300 km./hr. and climbs to 4000 meters in 17 min. Range 1400 km. Wing span 10 meters. Wing loading 71.9 kg./sq.m. Powered with a Hirth HM.508 280-hp. inline engine, it has a top speed of 310 km./hr. and climbs to 4000 meters in 16 min. Range 800 km. Wing loading 80.3 kg./sq.m. Characteristics and performances with both types of engines. *L'Aérophile*, July, 1939, pages 158–159, 3 illus., 2 tables.

U.S.A.

DC-4 Flight Tests—Their Relation to Large Air-Transport Designs. A. C. Reed. Data presented show that landing speed is well below the design limit established by past practice indicating an improvement in landing safety. Climb performance is better, especially with one engine dead. Level speeds are increased especially at the higher altitudes, and take-off is safer. The two-engined DC-3 is used as a basis of comparison. Economy curves comparing the DC-3 and DC-4 indicate that large airplanes, and the DC-4 in particular, pay their way in air-transport service, especially for the longer ranges over 300 to 400 miles. The 1000 individual tests made on the DC-4 during 74 flights occupying 90 hr. were made for stability, control, operation under extreme conditions, and performance. Preparation of the DC-4, flight tests, performance results, relation to large designs, tricycle alighting gear, reconsideration of the landing safety criteria, and pressure distribution tests are considered. *S.A.E. Jour. (Trans.)*, September, 1939, pages 407–412, 8 illus.

U.S.S.R.

Something Big for Aeroflot. Successor to the "Maxim Gorky" is said to have a loaded weight of 45 tons, a wing span of 206 ft., and six engines in the wing which give a total of 8000 hp. Empty weight is given as 31 tons, so disposable load would be 14 tons. Airplane is intended for the Civil Air Fleet and is said to have finished its tests. Brief reference. *Aeroplane*, August 30, 1939, page 286. Aircraft is capable of carrying 64 passengers and crew of eight. Brief reference. *Engineer*, August 25, 1939, page 211. U.S.S.R. L.1760 aircraft has a weight empty of 31 tons. Brief note. *Les Ailes*, August 24, 1939, page 6.

Air Transportation

Sweden. C. E. Dickerson, Jr. Possibilities for the use of American aircraft and aircraft equipment in Sweden, and details of the Swedish airline, Aktb. Aerotransport, of the Royal Swedish Aero Club, and of other private flying. *Aero Digest*, September, 1939, pages 40–41, 169.

Gliders

Air Ministry Official Notices. Towing gear of airplanes for glider towing is reconsidered in the light of an accident occurring recently. The existing type of towing cable release (hook attached to the airplane) must be replaced by an improved type of quick release approved against the latest requirements. New conditions of approval are given. Review of British Air Ministry Official Notice No. 20, as well as of other notices. *Aircraft Engineering*, August, 1939, page 333.

Bowlus Baby Albatross—Briegleb Utility. Bowlus Baby Albatross sailplane. Wing of elliptical plan form is tapered in thickness from inboard end of the aileron, although it is straight across to that point. Wing span 44 ft. Weight 205 lb. Gliding ratio 20 to 1. Best flying speed 45 m.p.h.

Model BG-6 Briegleb utility glider is a strut braced parasol monoplane with fully enclosed cockpit. Wing span 32 ft. 3 in. Aspect ratio (effective) 8.9 to 1. Weight empty 180 lb. Gliding angle 16.5 to 1. Short description of these gliders. Another article entitled "Soaring's Decennial" describes the results of the Tenth National Soaring Contest at Elmira. *Aviation*, August, 1939, pages 38–39, and 22–25, 27 illus.

René Leduc R.L-12 Motored Glider. Motored glider constructed by the chief pilot of the Aero Club of Nantes permits economical flying since it uses only an Ava 27-hp. engine. Maximum speed 122 km./hr. Ceiling 5800 meters. Wing span 10.80 meters. Landing speed 35 km./hr. Long description. *Les Ailes*, August 24, 1939, page 9, 3 illus., 1 table.

Propellers

Airscrew Diameters and Gear Ratios. Lt. Col. J. D. Blyth. Diagrams illustrated have been prepared to afford a rapid means of estimating the diameter of a propeller when design conditions of speed, height, engine power and r.p.m., and the gear ratio are known, or alternatively, of determining the most suitable gear ratio when the diameter is limited by considerations of tip speed or clearance. One diagram is for determination of the diameter or gear ratio and also the rotational tip speed. The second is for facilitating the evaluation of $b.hp./\sigma V$ without reference to a table of atmospheric constants. Third diagram obviates the necessity for arithmetical calculations in determining the true or helical tip speed from the combination of rotational tip speed and forward speed of the aircraft. *Flight, Aircraft Engr. Sup.*, August 31, 1939, pages 35–37, 3 illus., equations.

Feathering Propellers in Airline Transport Operation. M. G. Beard and E. W. Fuller. Paper previously abstracted from preprint. *S.A.E. Jour. (Trans.)*, September, 1939, pages 372–384, 25 illus.

Harmonic Torque Exciters. B. C. Carter. Mathematical analysis given for the motion and loadings of harmonic torque exciters was made to form the basis of design and to enable permissible conditions of operation to be specified. The mechanisms are used for exciting harmonic torques in propeller drives for experimental purposes. Harmonic inertia torque is produced by rotating a set of identical unbalanced pinions mounted in a cage and arranged symmetrically about a shaft axis with axes parallel to it. Pinions are driven either by a sun or annulus gear. In order to provide control of amplitude of exciting torque under any speed conditions of cage and pinions, two equal sets of pinions are mounted in the cage. Harmonic torque exciters have been proposed as a means of offsetting important resultant harmonic components of torque in engines as well as for experimental work. Expressions are derived for exciting torque, bearing load, and gear tooth loadings for an exciter operating not necessarily with uniform angular velocities, and driven either by a sun gear or by an internal or annulus gear. *Aircraft Engineering*, August, 1939, pages 306–308, 5 illus., many equations.

Measuring the Stresses in Vibrating Airscrews by Electricity. The De Havilland method of measuring vibration stresses consists of fixing along the blades of the propeller a series of precalibrated carbon resisters of known linear characteristics so that they must be stretched or compressed as the blade is deformed. An electrical current is passed through each of these resisters and changes in resistance caused by extensions or compressions are photographically recorded. Gauge made of carbon mixed with suitable binders is fitted with end contacts and forms an electrical extensometer of reasonable accuracy and reliability. Methods of measuring vibration stresses, the gauges, the specially designed amplifier, and other apparatus used, propeller-engine dynamics, the new propeller test house at Hatfield, and the suspension and cooling of engines are described. *Aeroplane*, August 30, 1939, pages 281–283, 7 illus.

Technical Notes. De Havilland has tested a "composite" propeller at Farnborough at overspeeds of 300 percent. Propeller consists of a metallic structure supporting the forces, and provided with light material to give the blade the profile and form desired. Bakelite is employed at first, then onazote, a drawn rubber. A piece of forged steel the edge forming the angle of attack and the base serving to attach the blade. Whole is covered again with molded onazote, vulcanized, and cemented. Brief reference. *Les Ailes*, August 31, 1939, page 7.

Miscellaneous

American Methods and Modes. J. I. Waddington. Comments on the Fleetwing Seabird, North Beach Airport, use of stratosphere aircraft and of giant aircraft, such as the D.C. 4, Duramold structure of the Clark cabin monoplane, visits to the Curtiss Buffalo plant and to Pan-American's Baltimore base, and behavior of sponsors or seawings on the new Clippers. To be continued. *Flight*, September 21, 1939, pages 251–255, 7 illus.

Aviation from Day to Day—April and May, 1939. Aircraft performance records, long-distance flights and performances, commercial aviation (tests, new equipment orders, supplies, and exploration), and military aviation (tests,

new equipment, orders, supplies, and accidents) are listed covering all countries. *L'Aéronautique*, July, 1939, pages 291–293, 6 illus.

The National Physical Laboratory. Research being undertaken in the William Froude Laboratory and dealing with screw propellers, airfoil-section blades, modifications to the cavitation tunnel, coasting vessels, hull resistance and vibrations. *Engineering*, September 15, 1939, pages 299–300.

A Record. A new world's speed record over a triangular course of 3150 miles is claimed by two Soviet civil pilots. Speed is given as 253 m.p.h. Brief reference only. *Aeroplane*, September 21, 1939, page 377.

The Second Aeronautical Exposition at Brussels. Account of the opening, and details of the French, Belgian, British, German, Bohemian and Moravian and Dutch exhibits of aircraft, engines, and equipment. *L'Aérophile*, July, 1939, pages 156A–156H, 14 illus.

Status of Records. Tables based on data of the F.A.I. up to May 1. *Luftwissen*, June, 1939, pages 210–212, 9 tables.

At the End of the First Year. R. H. Hinckley. Report of the first year's work of the Civil Aeronautics Authority. *U.S. Air Services*, September, 1939, pages 10–11, 13, 27–28, 1 illus., 2 tables.

Aircraft Instruments and Navigation

Better Bad Visibility. Reciproscope, a device for increasing range of visual observation in fog merely indicates the presence of some object not visible in normal circumstances, giving a warning in the form of a signal rather than of an actual preview. When visibility is reduced to about 200 yd., the crew of an aircraft approaching an object at 120 m.p.h. would only be given their warning one second earlier. When visibility is at the more normal maximum of 1000 yd., the pilot would be given an extra period of 4.25 sec., at the same flying speed, in which to prepare to avoid the obstacle.

Device artificially provides the oscillation by means of a movable mirror for the observer, placed at an angle of 45° relative to his line of sight, and sighting direction is made normal by fitting up an additional mirror to act as a form of periscope. First mirror is reciprocated so that the image is deflected through an angle of about 3°, though both angle and rate of movement can be adjusted. An opaque screen is fitted between observer and mirror. *Flight*, August 10, 1939, page 140, 2 illus.

Considerations for the Construction of Electrical Aircraft Instruments According to the Moving-Coil Principle. W. Fischer. Basis for the necessary new development of aircraft instruments according to the moving-coil principle, and proper construction of steel magnet arrangements. The most important design, the cylinder core-magnet arrangement, was investigated in regard to field course, and compass and temperature effects. A number of possibilities of application and explanations as to the constructive arrangement are given. Report of the D.V.L. *Luftfahrtforschung*, July 20, 1939, pages 391–401, 33 illus., many equations.

The Reduction of Position Error. K. Kenney. Instrument error may be due either to "indicator error" or "pitot-static error," while position error may arise from "inclination error" or "velocity error." The airspeed indicator and position error are described and general requirements for a pitot-static installation are given. Points to be watched when installing a pitot-static head are discussed. Progress made up-to-date is surveyed, and a few general rules to help keep the error in air-speed measurement as small as possible are outlined. *Aircraft Engineering*, August, 1939, pages 309–310, 313, 4 illus., 1 table.

Faure-Herman Fuel-Consumption Indicators. L. Frager. Indicators having sliding pistons, a turbine, or rotating pistons are illustrated and discussed. Faure-Herman fuel-consumption indicators are described in great detail in regard to principles of operation, construction, calibration- and altitude-correction curves, and endurance. Necessity for electrical transmission is pointed out, and results of a study of the effects of vibration on the contacts are given. Other types of equipment developed by Faure-Herman are described including: the receiver-totalizer for indicating total volume of fuel consumed at any instant; instantaneous indicator of quantity delivered; and a time recorder to record graphically the instantaneous quantity delivered. Practical utilization of fuel consumption indicators in cruising flight, in test flights, and as indicators of the condition of the engines is dealt with. *L'Aéronautique*, July, 1939, pages 286–290, 16 illus.

Nomenclature of Instruments and Controls for Surveying and Maneuvering by the Pilot. Starting equipment and controls for engines, propellers (Gnôme Rhône), flight maneuvers, armament, supply of oxygen, and electrical and other devices, and engine and navigation instruments are listed with the number required for each part, including a total of 76 controls and 43 instruments. The airplane considered does not carry de-icing installations or automatic piloting apparatus. *L'Aéronautique*, July, 1939, pages 263–264, 1 table.

Navigation

Raiding by Celestial Navigation. F. Chichester. Imaginary bombing raid carried out from a base in England by means of celestial navigation. Author seeks to prove his contention that a formation of bombers can be navigated on a raid of 1000 miles, above cloud the whole time, yet knowing its position to within less than one mile. The imaginary formation consists of a specially equipped navigation aircraft leading two heavily laden bombers. Navigational methods by which an approach is made to the target by flying up a Z-shaped estuary are described. Continued. *Flight*, August 31, 1939, pages 202f-202h, 3 illus.

Raiding by Celestial Navigation. F. Chichester. Really critical and final work in celestial navigation which is required as the special navigating aircraft and two heavily-loaded bombers approach their target is described. This is the concluding article on the imaginary raid carried out solely by celestial navigation. For several hours the bombers have been navigating accurately, not merely to know their position but also to find out the change in wind coupled with any pilotage or instrumental errors. As the whole period of critical navigation would not exceed 20 min., the navigators used the Datum-line method (a position line derived from the star at that time and passing through the objective). Final corrections made are explained in detail. Concluded. *Flight*, September 14, 1939, pages 237–241, 5 illus., 3 tables, equations.

The Flight Path in Curved Blind Flying, Especially in Rough Weather. H. Nautsch. By calculation and diagrammatic representation a method is presented which permits the determination of the flight path during a curve with regard to the wind. Possibility of using the figures produced, directly, as an aid in navigation, for example, in bad weather landings, is indicated. Method permits the expert in navigation and blind-flying to test the possibilities of application and accuracy of the methods used up to the present, and to facilitate their improvement. Short abstract. *Aircraft Engineering*, August, 1939. Complete article. *Luftfahrtforschung*, March 20, 1939, pages 148–156, 4 illus., 2 tables, 8 equations.

The Use of Mid-Time in Aerial Celestial Navigation. Ensign B. Sparks. Analysis demonstrating the magnitude of the error introduced by taking the midtime of the sights, and the conditions necessary for reducing it to a minimum. *U.S. Naval Inst. Proc.*, September, 1939, pages 1298–1300, 9 equations.

Electrical Equipment

Electrical Insulation for Aircraft. G. L. Moses. Effect of altitude on ambient temperature and atmospheric pressure, effect of atmospheric pressure upon dielectric breakdown characteristics of air and upon surface "flashover" voltage, effect of atmospheric pressure as determined by altitude on the breakdown voltage of air, and effect of reduced atmospheric pressure in "flashover" voltage for a typical material for various electrode spacings are shown in curves and discussed. Proposed dielectric tests for aircraft apparatus and comparison with other test standard, and proposed standard for creepage and striking distances on aircraft apparatus are shown in curves. *Aviation*, September, 1939, pages 28–29, 5 illus.

For Landing at Night. Rotax-Harley landing lamps for use in aircraft as well as with portable ground units. To control the upper half of the beam and spread it laterally, a special semicircular lens and diffuser is mounted behind the front glass panel of the aircraft lamp. The HO.7 8-in. aircraft lamp is fully retractable and is designed for 250-watt bulbs when used with a 12- or 24-volt system or 150-watt bulbs where generator is not fitted. Latest additions are the Models 13Y and 14Y 1000-watt and 1200-watt universally mounted projectors for use as searching lights when fitted to large aircraft. They are suitable also for landing and take-off and are designed to be fitted into the nose, fuselage, or leading edge. To avoid observation of the glowing filament from the ground after switching off, lamp and reflector is turned. Development of these aircraft lamps and their design are described and details are given of the portable self-generating ground unit. *Flight*, September 7, 1939, pages 233–234, 4 illus.

Electrical Equipment for Operation on Board Aircraft. Electric generators, current consumption and transmission; electric lines and clamps; radio interference; and requirements of electrical equipment operating at high altitudes including ignition interference, current supply, radio apparatus, antenna installations and electric charge phenomena. Review of papers presented before the V.D.E. *V.D.I.* August 5, 1939, pages 909–911, 1 illus.

Fire Prevention Equipment

Reducing Fire Risks in Aircraft. A Mathisen. Crash conditions which occur when an airplane is brought to rest from a state of motion so quickly that structural damage to the machine results are discussed with an example showing the effect upon a gasoline tank when an airplane is decelerated at about 10 *g*. Causes of fire in aircraft crashes, which were determined by the Fire Prevention Committee of the British Air Ministry, are referred to. Three types of fire-extinguishing fluids used in extinguishers for aircraft are described. Specifications for apparatus required by the British Air Ministry to utilize methyl bromide as a fire-extinguishing medium are listed. The Graviner automatic fire extinguishing equipment for aircraft, developed by Capt. H. M. Salmond and the writer in collaboration with the Royal Aircraft Establishment, is described. Drawing illustrates a fire-extinguishing installation in a four-engine airplane showing the location of the pilot's control and crash and gravity switches in the cockpit and flame and temperature switches and extinguisher bottle in each nacelle. *Aircraft Engineering*, September, 1939, pages 364–365, 1 illus.

Ice Elimination Equipment

Does an Electrostatic Charge Cause Ice Formation on Airplanes? R. Sirretta. The internal-combustion engine and friction of the air produce a positive charge which, when communicated to a metal airplane, violently attracts the drops of water which are charged negatively. Opinions of H. W. Roberts, H. H. Hucke, and M. Hartmann in regard to the electrostatic charge produced on aircraft are quoted, and the probability of ice forming on aircraft without the electrostatic charge is discussed. *Les Ailes*, August, 31, 1939, page 7, 1 illus.

New Aeronautical Terms. R. Giacomelli. Various terms to describe icing formation, rime, and clear icing are given in Italian and French. The author proposes "sopraggelo" (surfrosting) as a general term corresponding to icing and leaving undefined the type of ice formation. Very brief abstract. *Aircraft Engineering*, September, 1939, page 353. Complete article. *L'Aerotecnica*, February, 1939, pages 178–180.

Aerial Photography

Hurd Precision Aerial Camera. Mark Hurd precision aerial camera fits in a floating ring which rides on ball bearings in the shell of the mount. Incorporated in the ring are rectangular-shaped and integrally-built negative-lens view finders which produce a view of approximately the same area that the camera lens picks up and which are provided with steel wires to give a positive two-point intersection over the subject. Standard lens is a Goerz Aerotar F:6.8, either an 8½- or 10-in., both being interchangeable without loss of precision. Negative size is 9 × 9 in. Brief discussion. *Aero Digest*, September, 1939, page 155, 1 illus.

Testing Apparatus

Instruments Incorporating Thermionic Valves, and Their Characteristics. E. G. James, G. R. Polgreen, and G. W. Warren. Main tube characteristics which are of importance in instrument design, and types of tubes specially designed for instrument purposes. Principles are outlined of the various types of tube instruments for the measurement of alternating voltages (including "slide-back," peak, grid-leak, and anode-bend voltmeters), and of voltmeters and electrometers for direct voltages, and methods of measuring very small values of current and power are described. Reference is also made to other applications such as harmonic analysis, frequency measurement, and measurement of physical quantities. Tube-operated instruments are compared with other types of instruments, and possible future lines of development are indicated. Discussions before the Meter and Instrument and other Sections of the Institution are included with the author's reply. Communication from staffs of the Research Laboratories of the General Electric and M. O. Valve Companies, Ltd. and Salford Electrical Instruments, Ltd. *Instn. Electrical Engrs., Jour.*, August, 1939, pages 242–271, 38 illus., 1 table, equations.

A Portable Projector for Inspection. Baty Westminster portable projector is a self-contained unit. A darkened room is not necessary for its use, and the only precaution to be taken is that no direct light should be allowed to fall on the screen. Dallmeyer lenses provide true magnification

without distortion over the ranges 25 to 100 diameters. Brief note. *Aircraft Engineering*, August, 1939, page 331, 1 illus.

The National Physical Laboratory. Research being carried on in the Metrology Department in regard to line standards, electrical resistance verification of surveying tapes, interferometry, refractive index of air, measurements of thin mica, standards of mass and time, volumetric glassware, hydrometers, and barometers.

Research in the William Froude Laboratory is also discussed, including commercial testing, herring drifters, international comparative trials, performance in rough water, and maneuvering of ships. To be continued. *Engineering*, September 8, 1939, pages 275–277, 1 illus.

Materials

British Standard Specifications. Brass tubes for honeycomb radiators for aircraft (revised); aluminum-alloy sheets and coils and aluminum-coated aluminum-alloy sheets and coils (revised); eyeleted fuselage webbing (revised); fusion-welded air receivers; cold-rolled mild-steel strip; mild-steel drums for inflammable liquids; and cast-iron straightedges. Brief reviews of the specifications. *Aircraft Engineering*, August, 1939, page 331.

The National Physical Laboratory. Research in progress in the Metallurgy and Metrology Departments in regard to: performance of steel at elevated temperatures and caustic embrittlement of boiler plates; gas cylinders, refractories, and metallurgical chemistry; gage testing; aircraft spline gages; screw gages; and surface plates.

The experimental pneumatic slip-gage comparator in the course of development for rapid gaging is described and illustrated. There is no actual contact between gage to be measured and comparator, comparisons being made by measuring the resistance to flow of air through a fixed orifice. Once the apparatus is adjusted and calibrated, comparison of slip gages can be rapidly made, the accuracy being such that a difference of 0.001 in. in thickness gives a reading of $^1/_2$ in. on the graduated scale. *Engineer*, September 1, 1939, pages 249–251, 2 illus.

Some Recent Researches on the Internal Damping of Materials. R. Giovannozzi. Research results quoted show that for a group of apparently identical samples, damping may be quite different, and that, for an individual sample, damping depends upon its previous technological, mechanical and magnetic history. Investigations reviewed in the original article cover: Eccles and Thompson's investigation of visco-elastic properties of rubber; Spaeth's system for measuring tangential damping; Schenck's adaptation to obtain representation of the hysteresis cycle; magnetization effect studied by Esau and Kortum, Giebe and Blechschmidt; Foeppl's investigation of the relationship between internal damping and elasticity; Wegel and Walther's determination of normal and tangential damping for various metals at frequencies of between 5000 and 100,000 Hertz; and Ravilly's measurements made by studying damped torsional oscillations and by measuring heat developed in a wire up to the breaking point. Long abstract. *Aircraft Engineering*, September, 1939, page 353. Complete article and long bibliography. *L'Aerotecnica*, March, 1939, pages 245–272, 4 illus.

Metals

Age-Hardening. J. T. Norton. Mechanism involved in age-hardening, and properties of the newer age-hardenable alloys. Table shows the hardening element, hardening agent, and their high and low solubility weight and temperature for metals hardened by dispersion. *Iron Age*, October 5, 1939, pages 25–30, 2 illus., 1 table.

Research Progress—A Critical Review of Foreign Work. Problems of lubrication in connection with plastic working of metals, investigated by S. M. Golovin. Physical and chemical requirements of a lubricant, experimental procedure, behavior on heating, volatility and thermal stability, tests on corrosive properties, and behavior of lubricants during annealing of parts which had been subjected to three drawing operations are described. From "Metallopromyshlennosti," 1938/10/30. *Light Metals*, September, 1939, pages 333–334, 2 illus., 1 table.

Crystal Size and Mechanical Properties. J. C. Chaston. Recent investigations suggesting that the effect of grain size on mechanical properties is much less than is generally supposed are reviewed. Effects of grain size on hardness, tensile and fatigue properties, creep resistance, and notched-bar impact strength are considered, and results with gold, copper, copper alloys, lead, and steel are given. Only characteristics of steel seriously affected by large grain size is the Izod value, and in all other respects the materials are very similar. Same general trend will be found when dealing with metals other than steel. Before failures in service or fabrication are attributed to exaggerated grain size it is well to make certain that the trouble may not really lie in some other direction. Failures due to low notched-bar impact strength alone are comparatively rare. *Metal Treatment*, Summer, 1939, pages 58–60, 95, 2 illus., 6 tables.

Drop Forging of Steel and Light Alloys. K. Daeves and A. Ristow. Behavior of different steels in the drop-forging process, that is the ability of these steels to fill the forging dies at different forging temperatures, was examined. Composition of steels and light alloys used for forging tests and total height of light-alloy and steel stampings at various temperatures are shown in tables. The alloys tested are chiefly of the Al-Cu-Mg type, but one copper-free alloy, two containing large percentages of magnesium, and a commercially pure aluminum were included. The Al-Cu-Mg alloys at temperature used were more difficult to forge than medium hard types of steel and pure aluminum and copper-free alloy gave much more satisfactory results. Only pure aluminum, forged under half strokes of the hammer, and the Al-Mg-Si alloy forged under full strokes, were free from cracks, and in these two cases only can the mechanical treatment employed be considered to represent conditions applicable to industry. Translation of abstract from *Stahl und Eisen*, Volume 58, No. 51, 1938. *Metal Treatment*, Summer, 1939, pages 82–86, 4 tables.

The Sliding of Metals, Frictional Fluctuations, and Vibration of Moving Parts. F. P. Bowden, L. Leben, and D. Tabor. The analysis of kinetic friction between moving metals shows that it does not remain constant. Metals may move by a process of stick and slip, and the friction, area of contact, and surface temperature may fluctuate rapidly during motion. Exact type of sliding depends upon relative melting points of the different metals. There is evidence that friction is due to formation and subsequent breaking of the metallic junctions between surfaces, and these junctions may be of three distinct types, the characteristic of similar metals giving the highest friction and wear.

When dissimilar metals slide together one surface may pick up material from the other and frictional behavior may change over to that characteristic of similar metals. Minute stick slips inherent in the sliding may set up vibrations in the moving parts. Amplitude and frequency of these vibrations will depend on mechanical properties and restraints of the moving parts. Resultant motion between surfaces will be complex and will be determined by the nature of the stick slip, natural frequency of the system, and speed of the forward motion. This resultant motion governs the friction and wear. Results of experiments are discussed in great detail and apparatus used is briefly described. *Engineer*, August 25, 1939, pages 214–217, 16 illus.

New Developments in Automotive Materials. New Carboloy special carbide containing tungsten, tantalum and titanium carbides is used for heavy cutting. Lincoln Fleetweld 10 welding electrode is designed particularly for welds for finish beads, on U-groove welding in the downhand position. Kennametal grade KH for machining hard steels as well as annealed stock has a hardness of 91 Rockwell A and a strength, on transverse rupture tests, of 224,000 lb./sq.in. Brief descriptions. *Automotive Industries*, September 15, 1939, pages 264–265, 2 illus.

Corrosion and Protective Coatings

The Corrosion of Metals. O. P. Watts. Corrosion by oxygen depolarization is discussed in regard to evolution of hydrogen at the anodic member of couples, corrosion by displacement of cations other than hydrogen, pure metals *versus* galvanic couples in corrosion, and effect on corrosion of varying the extent of cathodic surface. Chemical depolarizers, effects of distance between couples, of depth of immersion, of resistance of the circuit, and of increase in surface of anodic and cathodic metal, and differences in oxygen concentration are considered. Concluded. University of Wisconsin bulletin. *Engineer*, August 25, 1939, pages 221–222, 5 tables.

Metallic Coatings—Their Atmospheric Corrosion-Resistance and Protection Value. S. G. Clarke. Effects of various corroding influences indoors, including moisture, gaseous impurities, and contamination of surfaces by fingermarking, and dust. Tables give the behavior of 0.01-in. and 0.0001-in. coatings of tin, nickel, cadmium and zinc on steel in a humid atmosphere, and appearance in severe indoor test of steel coated with nickel, copper, tin, lead, zinc, and cadmium. Concluded. Electrodepositors' Technical Society paper. *Metal Industry*, August 25, 1939, pages 181–184, 1 illus., 2 tables.

Corrosion and Protection of Magnesium Alloys. Production of phosphate, borate, silicate, and other coatings on magnesium alloys, and electrolytic and special protective treatments. Various patented methods are described, including: coatings of borate, phosphate, or other compounds of magnesium also using an oxidizing compound; three methods of treatment for silicate coatings; various chromate treatments; operating dichromate baths; selenium treatment by spraying; chrome-phosphate process; electrolytic deposition of fluoride; use of water-soluble fluorides; strip-sealing process developed by Cellon, Ltd.; Elektron foil treated with Cerrex magnesium strip; and problems of corrosion and protection raised by use of magnesium-alloy sheet for fabrication of containers designed for liquid fuels and oils, especially leaded and alcohol fuels. *Light Metals*, September, 1939, pages 313–316, 1 illus.

Ematal Process for Anodic Oxidation. E. Herrmann. Ematal process described is used in Switzerland for producing anodic films of high opacity on aluminum alloys, and differs from other anodic oxidation processes in that pigment is introduced into the oxide coating in the course of its formation. Pigment is produced directly from salts, such as those of titanium, zirconium, and thorium, which are dissolved in the electrolyte itself. Process is employed in the production of culinary utensils. *Light Metals*, September, 1939, pages 324–325, 7 illus.

Iron and Steel

Stainless Clad Steel by a Unique Process. Babcock and Wilcox Croloy composite plate is composed of thin layers of chromium-alloy steel (12 to 14 or 16 to 18 percent Cr) electric-resistance welded to a base plate of carbon or carbon-molybdenum steel by individual spot welds that overlap lengthwise and crosswise of the plate, bonding the alloy to the plate over the entire surface. Process is made possible by the use of two or more sheets of alloy (stainless) steel with a sheet of nickel between the alloy and base metal. Process and permanence of the bond are described. *Metals & Alloys*, September, 1939, pages 287–289, 6 illus.

Non-Ferrous Alloys

Fatigue of Light Metal Alloys. R. L. Templin. General conclusions reached from laboratory tests on factors affecting fatigue values, effects of stress raisers, and the use of fatigue values are discussed. *Metals & Alloys*, August, 1939, pages 243–245, 2 illus.

The Influence of the Number of Quenchings and of the Annealing Time on the Age Hardening of Al-Cu-Mg Alloys. P. Brenner and H. Kostron. For sheets of the Al-Cu-Mg alloys, Bondur 17/65 and 17/39, the influence of the various longer and frequently repeated toughening (hardening followed by tempering) and annealing treatment on the time of room-temperature age hardening was investigated. For the first toughening with the increasing annealing time, the yield-point and strength approached, after full room-temperature age hardening, toward a parabolic function of its end value. In order to reach the highest value with more satisfactory approximation, an annealing of about 45 min. at 505°C. was necessary.

In the practically applied range a variation of annealing time caused no considerable variation of the period of the principal age hardening. For similar total annealing time, a subdivision of the annealing time by means of intermediate quenching caused no change of age hardening. Report of the Institute of Light-Metal Working Research, Hanover. *Luftfahrtforschung*, July 20, 1939, pages 362–369, 31 illus.

Non-Ferrous Metals. New laboratories for the British Non-Ferrous Metals Research Association are described including the melting shop, and the mechanical-testing, physics, and corrosion laboratories. *Automobile Engineer*, August, 1939, pages 297–298, 4 illus.

Use of Magnesium Alloys in the European Automotive Industry. H. Altwicker. Advantages of magnesium alloys in regard to weight reduction, excellent machinability, tool costs, and ease of handling are discussed. For highly stressed castings heat-treated aluminum-bearing magnesium alloys are used. For applications involving impact stresses, magnesium alloys containing zinc in addition to aluminum have been developed. Alloys containing manganese welded readily, whereas silicon-bearing alloys are preferred for castings that have to be pressure tight. In wrought magnesium alloys, aluminum is also the most important alloying element. Rules for the design of magnesium-alloy parts to utilize the inherently good endurance characteristics of these alloys to best advantage are reviewed. Applications of the use of cast magnesium in the automotive industry are shown. *S.A.E. Jour.*, September, 1939, pages 9–13, 17–19, 22 illus.

Age-Hardening Magnesium Alloys. W. F. Chubb. Although the lead-magnesium alloys considered possess no members of structural importance, they exhibit physico-chemical properties of some interest. Early work of Heycock and Neville, and Grube, the chemistry of $PbMg_2$, electromotive characteristics, lattice structure of intermetallic compound, and form of

resistivity curves are considered. Continued. *Light Metals*, September, 1939, pages 329–332, 9 illus., 6 tables.

American Practice in Die-Casting Magnesium. H. Chase. Production, properties, and potentialities of ultra-light alloy pressure die castings, and suitable composition ranges. Disadvantages of air injection, factors influencing soundness, influence of heat treatment, and resistance to salt water are discussed. *Light Metals*, September, 1939, pages 320–321, 3 illus., 1 table.

Beryllium—A Versatile Element. L. L. Stott. Although beryllium is often mentioned as a light metal of particular interest to aviation, no commercial use of the element in the light-alloy field has actually been made to date. It seems likely that the amazing capacity of the metal to harden copper, nickel, and iron will remain its most important contribution. Properties of pure beryllium and beryllium-copper, beryllium-copper-cobalt, beryllium-nickel, and beryllium-aluminum are considered. *Iron Age*, September 21, 1939, pages 42–45, 6 illus.

Internal Strains in Solids. "Glide and Hardening of Metal Single Crystals," Andrade. "Problems of Plastic Gliding," Orowan. "Age-hardening of Copper-Aluminium Alloys," Preston. "X-ray Evidence of Intermediate Stages during Precipitation from Solid Solutions," Bradley. "Structure of a Cold-Worked Metal," W. L. Bragg. "Crystalline Structure and Deformation of Metals," Wood. "Lattice Distortion of Cold-Worked Metals," Brindley. "Mechanical Effects of Intercrystalline Boundaries," Chalmers. "Internal Friction in Solids," Zener. "Internal Strains and Magnestism," Becker. Papers presented before conference of the Physical Society and University of Bristol are summarized, particularly those aspects associated with light alloys. *Light Metals*, September, 1939, pages 327–328.

Machining of Aluminium and Its Alloys. J. H. Dickin and G. A. Anderson. Methods of testing the machinability of pure aluminum, and the cast, wrought, free-cutting, and lead-bearing alloys. Recommendations are made in regard to turning and boring, speeds and feeds, lubricants, planing and shaping, milling, drilling, screw cutting and threading, sawing, and grinding. Paper for British Institute of Metals symposium. *Metal Industry*, September 8, 1939, pages 221–226, 4 illus.

Testing of Metals

Chemical Analysis of Aluminium. Method described by R. Bauer and J. Eisen (Agnew. Chem., 1939/52/429) for determining iron and copper contents rapidly and accurately by photometric means, and that presented by Schoenlau (Aluminium, 1939/21/528) for determination of chromium in unalloyed aluminium are discussed. Short note. *Light Metals*, September, 1939, page 334.

Determination of Surface Roughness by Light Reflectivity. Differences in refractive qualities of various types of machined surfaces on metal are effectively used in the new Insulation Development Corporation device to indicate surface smoothness, and a reading is obtained on the single small area no larger than a point of light. Light from a 32-cp. automobile fog lamp bulb passes through an aperture and plano-convex condensing lenses to the surface examined and the reflected light is picked up by a selenium cell, amount of light energy being shown on a microammeter. Brief description. *Iron Age*, October 5, 1939, page 48, 1 illus.

Investigating Surfaces. Examination by means of the electron diffraction camera. Apparatus described was used by G. I. Finch for recording the condition and changes in the surface of a material. It consists of collimating specimen and camera sections. Typical electron diffraction patterns obtained with the camera are illustrated and discussed, including: thin gold film deposited on copper, lubricating graphoid surface formed on a cast-iron face, an α iron skin formed on mild steel, chromium platings on copper, on nickel, and on iron, and cuprous chloride film formed on copper degreased with trichlorethylene. *Automobile Engineer*, August, 1939, pages 289–291, 9 illus.

Non-Destructive Testing. A. Salmony. Modern methods of examining materials to determine faults in new or used parts. The "Super-Microscope" or "Electron-Microscope" is described, and that of Siemens and Halske is illustrated. Operation is based on the application of rays of much smaller wave length than that of the light rays upon which ordinary microscopes depend. The Richard Seifert X-ray apparatus, and special bearing-testing instrument, crystal-structure working table, "Roentgen-Microscope" with four working places for carrying out microstructure examinations by the Debye-Scherrer process by the rotating crystal process, the reflection and the Laue method, and a new and simplified instrument by the same company as well as the Philips' "Metallix" apparatus are described and illustrated.

Other illustrations discussed include: rupture in the canvas foundation of an automobile tire; segregations in bearing metal; texture diagram of fibrous material; Debye-Scherrer diagram of composition of alloys; macroscopical structure analysis of a carburetor; X-ray investigation of steel balls; diagrams of a steel ring before and after heating; electron picture of a colloidal iron thread; and electron images of an unstretched and a stretched caoutchouc membrane. *Automobile Engineer*, July, 1939, pages 249–252, 15 illus.

Welding

The Effect of Alloying in Metallic Arc Welding. R. W. Emerson. Problems involved in the welding of high-alloy and low-carbon steels, particularly from the standpoint of the alloying produced when a portion of the kerf surface of the base metal is melted and alloyed with the metal deposited from the electrode. Effect of rapid heating and cooling on the parent metal, and effect of alloying when the base metal is melted and alloyed with the deposited metal must be considered when metallic arc welding ferrous alloys. Low-carbon and high-alloy stable austenitic steels are not affected adversely physically by welding heat and effect of alloying is the only consideration. In welding low-carbon or relatively low-alloy steel with austenitic electrodes, an electrode should be used in which the austenite is sufficiently stabilized so that after dilution with low-carbon or low-alloy steel it will still remain as stable austenite and not revert to martensite. A narrow band of martensite is not formed along the fusion line of a weld made with an austenitic electrode and a low-carbon or low-alloy steel. Each layer of deposited weld metal is entirely austenitic or dilution is sufficient to cause reversion of the entire layer to martensite. Use of 17 percent chrome electrode does not appear suitable for either 25-12 or 18-8. *Welding Jour., Welding Res. Sup.*, October, 1939, pages 381–392, 21 illus., 3 tables.

Further Studies of the Spot Welding of Low Carbon and Stainless Steels. W. F. Hess and R. A. Wyant. Results of studies made on hot-rolled, annealed, and pickled low-carbon steel, 0.047 in. in thickness, and on 18-8 annealed stainless steel, 0.068 in. in thickness, in both the dull and polished finishes. Strength characteristics, sheet-to-sheet and electrode-to-sheet resistance characteristics, and results of microscopic examination are described in detail. *Welding Jour., Welding Res. Sup.*, October, 1939, pages 348–354, 17 illus.

Precision Welding by the Resistance Method. G. J. Oswald, E. J. Bates, and R. L. Hous. Factors affecting the strength and ductility characteristics of projection welds were studied, and tests were made in balancing all the equipment electrically. Results are discussed, and rules are given for the guidance of the designer in working out details of resistance-welding fixture construction. Description of research undertaken at the National Cash Register Company. *Welding Jour.*, October, 1939, pages 581–587, 7 illus., 2 tables.

Miscellaneous Materials

A New Form of Expansion Liquefier for Helium. A. H. Cooke, B. V. Rollin, and F. Simon. The expansion liquefier described yields a supply of liquid helium in a Dewar vessel and is very economical in liquid hydrogen. *Rev. Scientific Instruments*, September, 1939, pages 251–253, 1 illus.

Exothermal Decomposition Temperature of Wood—Impregnated with Flammable Organic Liquids. K. A. Kobe and F. L. Goin. Exothermal reactions in thermal decomposition of wood are distributed over a considerable range of temperature and depends upon rate of heating. An apparatus and procedure developed give reproducible results and allow the study of the effect of various materials on the exothermal decomposition temperature. Moisture in the wood has no effect on the exothermal decomposition temperature. Gasoline, kerosene, and light oil lower the exothermal decomposition temperature, heavy oil causes no change, and creosote increases it. *Industrial and Engineering Chemistry, Ind. Ed.*, September, 1939, pages 1171–1172, 2 illus., 1 table.

Bearings

Investigation of Lead-Bronze Castings in the D.V.L. Bearing Testing Machine. G. Fischer. Bearing properties of twelve lead-bronze alloys were investigated in the D.V.L. bearing machine for tempered and hardened journals. The tests were extended to the determination of bearing capacity limits and behavior under repeated stress as well as of regulation of oil supply. D.V.L. report. *Luftfahrtforschung*, July 20, 1939, pages 370–383, 42 illus., 5 tables.

Electrodeposition of Silver-Lead Alloys for Bearings. C. L. Faust and B. Thomas. Research described was undertaken under sponsorship of the American Silver Producers' Research Project, and was directed mainly toward the production by electrodeposition of a Ag-Pb alloy containing 3 to 5 percent Pb, by a process that could be carried out continuously and that would give uniform alloy compositions over an extended period of operation. Authors were specifically interested in producing an AG-Pb alloy containing 3 to 4 percent Pb electrodeposited on a full-size bearing for an aircraft engine. Electrochemical Society paper. *Metal Industry*, September 15, 1939, pages 253–256, 4 tables.

Tests of Light-Metal Bearings in Test Machines and Aircraft Engines. A. Buske. Requirements to be observed in the use of light metal for plain bearings. In the investigations described the magnesium alloys 10 and 11 were not loaded in the test machine much over 350 kg./cm². In the case of less resistant alloy materials and in the case of magnesium alloy 12, the strength limits were exceeded at 600 kg./cm². On steel bearing parts, these magnesium and aluminum alloys are only conditionally applicable. For greater surface load at greater bearing speeds, these materials, as a result of high bearing temperatures, can be used in steel bearing elements only as loose bushings. As fixed bushings in rigid steel bearing parts, and in steel housings and thin-wall hub ends, they can be loaded only up to temperatures of approximately 20° to 30°C., and as a result are only loadable up to low temperatures and low r.p.m. The hard alloys, 5, 6, 7, and 14 should be used only for highly-loaded bearings.

Results of tests made in German plants, such as in the B.M.W. experimental engine plant, in attempts to use light metals as bearings. Tests in single-cylinder engines, in bearing positions in auxiliary shafts, and in drives are described as well as those in the bearing testing machine, including limiting load tests of bearing elements of different form, tests of form design principles by oil-film pressure measurements, and overload properties of light metals. V.D.I. paper. *A.T.Z.*, July 10, 1939, pages 355–363, 21 illus., 1 table, equations.

Fuels and Lubricants

Antioxidants for Castor Oil. G. O. Inman, Rock Island Arsenal. While castor oil as a lubricant in ordnance material can be used in contact with rubber packings with no harmful effects, it becomes oxidized with age attacks brass parts, and causes undesirable corrosion. Work described was undertaken to find an inhibitor which would prevent oxidation. Acid number of castor oil with various antioxidants during accelerated oxidation tests are shown. All three cresols are mild prooxidants but the meta isomer is stronger than the ortho or para, *o*-nitrophenol being a slightly stronger prooxidant than *p*-nitrophenol. Benzyl alcohol is a weaker prooxidant than the other three isomers, the cresols. *Industrial and Engineering Chemistry, Ind. Ed.*, September, 1939, pages 1103–1104, 3 illus., 1 table.

Phillips to Make New Aviation Gasoline Ingredient from Natural and Refinery Gases. Neohexane, the new high-octane aviation-gasoline ingredient, is manufactured by the thermal alkylation method, the raw materials being ethylene and isobutane. Method of manufacture developed by Phillips Petroleum Company for the commercial synthesis of neohexane is described. Advent of neohexane is expected to overcome certain limiting factors now prevailing in the path to still higher octane-number fuels. Neohexane has an octane number slightly lower than chemically pure isooctane but has a better tetraethyl-lead susceptibility. Quantities of tetraethyl lead required to give neohexane antiknock properties, physical properties of neohexane, and A.S.T.M. distillation data of neohexane, commercial isooctane, and a 45-55 blend of the two are shown in tables. *Oil & Gas Jour.*, October 5, 1939, pages 40, 42, 3 illus., 3 tables, 1 equation.

Production of Aviation Fuels by High-Pressure Hydrogenation. E. V. Murphree and E. J. Gohr, Standard Oil Companies. Production of aviation gasolines, blending agents, and 100-octane fuels by high-pressure hydrogenation. Typical aviation naphtha hydrogenation plant at conversions of 50–75 percent per pass yields 80–95 percent of 75–78 octane hydrogenated naphtha having excellent stability, high lead susceptibility, low sulfur content, and good color. Hydrogenation of isobutylene dimer and isonormal butylene codimer increases octane number from 82–84 to 97–100. Tables show laboratory inspection data, properties of hydrogenated aviation naphthas from four feed stocks, comparative inspections of virgin and hydrogenated aviation naphthas, commercial-scale hydrogenation of codimer, hydrogenated isobutylenes, 100-Army-octane fuel from hydrogenated aviation naphtha, hydrogenated codimer, and isopentane with 3.0 cc. of tetraethyllead per U.S. gallon, and aviation fuels of 102- and 104-octane number prepared from hydro codimer blending agent and hydrogenated aviation gasoline. The blend given for the 100-Army-octane fuel meets the current specifications of the U.S. Army and British and French Air

Ministries for this grade of naphtha. *Industrial and Engineering Chemistry, Ind. Ed.*, September, 1939, pages 1083–1089, 8 illus., 8 tables.

Diesel Fuels. A. T. Wilford. Latest developments in oils for high-speed Diesel engines are discussed including: physical characteristics; fuel rating; determination of ignition quality; ignition quality and physical characteristics; cetane numbers and engine performance; B.S.I., Swedish, and A.S.T.M. specifications; substitutes for petroleum fuels; and current high-speed Diesel fuels. Characteristics of high-speed Diesel fuels recently examined by the author are given in a table showing that the oils exhibit a wide variation, particularly in regard to specific gravity and distillation range. *Automobile Engineer*, July, 1939, pages 254–256, 1 table.

Engine Design and Research

Calculation and Design of High Speed Crankshafts. Cornelius. Results which may be applied by the engine designer in his work, rather than methods of testing and calculation, are discussed. Calculation of the following are considered: effective torsional moments and reactive torsional moments due to gas and mass forces; reactive torsional moments due to vibration (idealized systems, natural vibration number and form for the driving gear, the operating excitation of gas and mass forces, and the resonance curves of machines and the additional stresses in the machines caused by vibration); the peak of torsional loads on crankshafts; bending stresses; and load-carrying capacity of crankshafts.

The discussion of crankshaft design includes: selection of material for motor-vehicle and aircraft engines; design with reference to vibration and to load-carrying capacity; fixing of resistance moments of crankpins and cheeks; fillet radius in the crankpin bore and coldworking of the bore on forged crankshafts; oil bores; form of throw for high design resistance in cast shafts; problem of counterweights; design for manufacture; dimensions, tolerances, and standards; and examples of design. V.D.I. paper. *A.T.Z.*, July 25, 1939, pages 385–393, 20 illus., many equations.

Development and Manufacture of Heavy-Oil Aircraft Engines. F. W. Achterberg. General discussion reviewing progress made in the design of pistons, cylinder liners, gear mechanisms and shafts, combustion with injection, pumps, nozzles, blowers, and exhaust-gas turbines. Flights made by the author and others in Diesel-powered aircraft are briefly referred to. *Luftwissen*, June, 1939, pages 191–195, 11 illus.

Determination of the Operating Conditions for Gasolines in Aircraft Engines. A. Labarthe and Lidia Manson. Tests were made at the request of the Air France airline to determine at what intake pressure an Hispano-Suiza 12Y supercharged engine would start to detonate when it operates on gasolines of 85, 91, or 100 octane numbers. Installation of the photocathodic manograph on the Hispano-Suiza 12Y engine, indicator cards taken in detonation tests with fuels of these three octane numbers, and power curves in function of the intake pressure are illustrated. Test apparatus is described and results obtained, with these gasolines are discussed. *L'Aéronautique*, July, 1939, pages 273–276, 8 illus.

Investigation of Inertia Mass and Frictional Moment of a Torsional Vibration Damper. F. Mueller. Tests are described which demonstrate that a rule exists between damping mass and most advantageous frictional moment. A method of presentation was found which makes it possible to read the range of frictional moment required for the most suitable damping for each moment of inertia. *A.T.Z.*, July 25, 1939, pages 409–410, 4 illus.

Material Strains Developed by Impact-Like Forces in High-Speed Piston Machines. E. Seiler. Stresses resulting from the propagation of waves which are due to sudden loading or unloading and which disturb the equilibrium of the material structure are considered. These disturbances travel with the velocity of sound and, at all places of a cross-sectional or structural variation, are subject to a change derived from the laws of refraction of the waves. Such stressing and the resulting impact stresses are illustrated by simple examples. Discussion is limited exclusively to the longitudinal vibration of rod-shaped machine parts, but it can also be applied to torsional and bending vibration. These types of vibration are also propagated according to the same basic laws and likewise are subject to the laws of reflection. They are of importance in particular in crankshafts in which hardened and unhardened parts become detached with stress changes as the result of reflection. *A.T.Z.*, July 10, 1939, pages 371–375, 9 illus., 19 equations.

Molecular-Physical Problems of Lubrication. K. L. Wolf. Nature of lubrication problems, and how the theory of molecular physics can supply the theory of lubrication with certain fundamentals are demonstrated by examples from the fields of boundary and full lubrication. Importance of polar groups for the boundary surface lubrication; adherence of polar boundary layer; nature of internal lubrication, extended molecules and molecule clusters; mechanism of friction; importance of overmolecules; mole arrangement as a basis of molecular viscosity; importance of the association for internal lubrication; and analogy between viscosity and thermal conductivity. *V.D.I.*, July 1, 1939, pages 781–786, 8 illus., 2 tables, equations.

Aviation Fuels and Engines—Some Observations on Their Present and Future Development. F. R. Banks. Future engine developments for outputs between 2000 and 4000 hp., and the form which such engines will take are discussed, including optimum cylinder sizes and number of cylinders. Aviation fuel position in Great Britain is reviewed, and some work on very high duty aircraft engines which the author has done in conjunction with the British Air Ministry and one of the aircraft engine manufacturers is described. A characteristic of the American two-valve hemispherical cylinder head relative to British four-valve engines in regard to fuel behavior is considered. New developments, such as the treatment of poppet-type exhaust valves with Brightray, are mentioned. Views on the single sleeve valve and, in detail, latest information on the development of the sintered-aluminum-oxide spark plug, are presented. Direct injection of gasoline is also considered. Low fuel consumptions of the Napier Dagger engine with 100-octane fuel and of the German Argus As.410 engine are mentioned. Discussion of paper by A. L. Beall who disagrees on effects of fuels and swirl, and the author's reply are included. *S.A.E. Jour. (Trans.)*, September, 1939, pages 389–406, 16 illus., 5 tables.

Petrol Injection. A. Labarthe and A. Ponomareff. Fuel injection produced an increase in horsepower over the whole speed range (1500–3000 r.p.m.) compared with carburetor performance in tests with a 10-hp. single-cylinder unit. The improvement varying between 12 and 17 percent, and a reduction in specific fuel consumption of the order of 7 percent could be realized under certain conditions. The method of injection into the cylinder was used, injection being carried out either during the induction or during the compression stroke. The former method is favored by the authors although the latter, if functioning properly, has the greater tendency to reduce detonation. Very brief abstract from *Comptes Rendus de l'Academie des Sciences*. *Automobile Engineer*, July, 1939, page 248.

Resonance Vibration in the Induction and Exhaust of Inline Engines. P. Lutz. Vibration processes in single branched ducts with excitation at several points may be reduced, by decomposition of the delivery-pipe system into individual pipes "open" at the points of excitation, to a well-known simple relationship. To be continued. Short abstract of report of the Hermann Goering Aeronautical Research Institute, Braunschweig. *Aircraft Engineering*, August, 1939, page 315. Complete article. *Luftfahrtforschung*, March 20, 1939, pages 139–147, 16 illus., 28 equations.

Resonance Vibrations in the Induction and Exhaust Ducts of Inline Engines. P. Lutz. Vibration processes in branched ducts are treated, and the results are applied to the calculation of the processes in the induction lines of a 12-cylinder double inline engine. Continued. Report of the Hermann Goering Aeronautical Research Institute, Division for Engine Research. *Luftfahrtforschung*, July 20, 1939, pages 384–390, 14 illus., 1 table, 14 equations.

Engine, Fuel and Lubricant Testing

Evaluation and Testing of Electrical Engine Indicators. F. Lichtenberger. Recommendations are given for standardizing certain characteristics of electrical engine indicators, especially the piezoelectric quartz indicator, but they may be applied to other systems. The suggestions on methods of testing are so general that they are applicable to any type of indicator except the stroboscopic type. Discussion covers: screwed connections; size and weight; measuring range; cooling; length of operation; room- and high-temperature calibration; sensitivity to shock and natural frequency; the D.V.L. quartz-indicator method of measuring and measuring results; oscillograph; amplifier; and electric wires and connections. A record sheet is given for use in the evaluation and testing of an electrical indicator. *A.T.Z.*, August 25, 1939, pages 451–456, 5 illus.

Experiences with Temperature-Measuring Paints. W. Hohenner. Experience in the use of paints of various colors in the determination of the distribution of temperature on engine cylinders. Paints are kept in alcohol until used and are sprayed on the object to be tested by means of the conventional spray gun or by brush. It is best to coat a part with a strip 10-mm. wide so that measuring paints of several other colors can also be used on the part for a more rapid determination of temperature limit in degrees. Paints are difficult to remove when applied by spraying. Boiling in glysantin at 150° is not always as satisfactory as manufacturers claim. Mechanical removal by scraping or sandblasting frequently is not possible. Brief note. *Luftwissen*, June, 1939, pages 195–196, 1 illus.

Measurement of Knock Resistance in Gasoline Engines. R. Schuetz. Combustion and detonation processes in a gasoline engine are discussed, and measuring methods are proposed which may be suitable to replace the elastic-bar indicator. The author believes that detonating resistance can be measured by three methods. The amplitude of oscillation of the detonating frequency can be determined since the greater the charging portion which is burned first after reaching the self-ignition conditions, the more intense is the formation of the pressure waves and the greater the amplitude of oscillation of the detonating frequency. Length of the period can be determined since two quartz transmitters will indicate the start of the detonating frequency differently. If a uniform sound velocity is assumed in the entire combustion chamber, it is possible, by means of simultaneous use of several quartz chambers, to determine the local position of the detonating center and consequently the magnitude of the charging portion which is burned upon introduction of the self-ignition conditions and which determines the detonation intensity. The combustion period can be determined. If it is assumed that the end of combustion coincides as to time with the start of detonation, then it can definitely be determined whether or not a cylinder detonates. Since, for a charging portion which burns in a detonating manner, an apparently infinite flame velocity is reached, the combustion period will vary by jumps. *A.T.Z.*, July 10, 1939, pages 364–370, 22 illus.

Cathode Vacuum Distillation of Aircraft-Engine Oil. M. Richter. Distillation apparatus consists of a copper vessel of 200-cu.cm. capacity and a Bruehl receiver with a brass cover containing a connection device for a three-stage mercury pump, for a Geissler tube for qualitative observation of cathode vacuum, as well as a connection for a McLeod manometer for measurement of receiver vacuum. Point of German silver, used for measurement of oil-vapour temperature, is placed in its upper portion to avoid radiation. By means of this distillation apparatus a vacuum of 0.001 mm. Hg can be reached.

Examples show the possibilities of fractionation, supplemented by investigations according to the D.V.L. oxidation process and ring analysis, for determination of constituents and for judgment of the practical behavior of lubricants. Only a part of the fractions of each lubricant could be examined. Further research will be necessary to provide a complete picture of the constituents of lubricants, in the order of the boiling points of the constituents, by the extension of the research described here to the total fractions and particularly to the distillation residues. Short abstract of D.V.L. report. *Aircraft Engineering*, August, 1939, page 316. Complete article. *Luftfahrtforschung*, April 20, 1939, pages 212–217, 7 illus., 4 tables.

The High-Speed Geiger Torsiograph. New high-speed torsiograph for measuring torsional vibration. Due to the much smaller pulley diameter, the moment of inertia of the oscillating parts is considerably reduced, and the pulley responds immediately to the smallest change in angular velocity of the driving shaft over the whole frequency range of the instrument. Two timing pens are provided, one for drawing a damped vibration curve of carefully calibrated frequency (either 3000 or 1500 vibrations per minute) and the other for marking consecutive revolutions of the driving shaft when used in conjunction with a make-and-break device, or for marking $^1/_{10}$- and $^1/_2$-sec. timing intervals when used in conjunction with a precision contact clock. For high-frequency recording the normal tracing and timing pens are replaced by similar fittings having small silver points at the recording ends instead of ink ducts, and records are made on either a very heavily leaded paper or on a waxed paper. Special applications of each type of Geiger torsiograph, and an accurate and compact tachometer used in connection with torsiograph investigations described. *Automobile Engineer*, August, 1939, pages 293–295, 3 illus.

Engines

The 175 H.P. Ranger. Ranger Model 6-440C-2 six-cylinder inverted inline engine described was developed to meet U.S. Army Air Corps requirements for a primary-trainer engine. New "tuned" intake manifolds and hotspot impart a ramming effect by properly utilizing mixture pulsation in the intake manifolds to assist in charging the cylinder. This design provides mild supercharging without increase in weight, design complication or expense of a supercharger, and makes possible a b.m.e.p. of 131 lb./sq.in. on 65-octane fuel and of 152 lb./sq.in. on 80-octane fuel. Power 175 hp. at 2450 r.p.m. Bore 4.125 in. Stroke 5.5 in. Displacement 440 cu.in.

Compression ratio 6/1. Weight 355 lb. Long description. *Aero Digest*, September, 1939, page 64, 3 illus. *Aviation*, September, 1939, pages 38, 42, 4 illus., 1 table.

An Advanced Two-Stroke Engine Design. Jameson high-performance supercharged two-stroke liquid-cooled vertical four-cylinder inline engine. Water jackets are tapered upward giving the cylinder block a triangular form. Two camshafts situated on either side of the crankcase are in effect crankshafts, each incorporating four throws operating a similar number of miniature connecting rods. Small ends of these rods are located in lower ends of the levers or links actuating the valves. Each valve is of the sliding type with a small rectangular aperture situated approximately three-quarters of its length toward the top. Reciprocating motion of the valve up and down a chamber enables its aperture to open and close the port. Combustion chamber is shaped to form an inverted deflector, and mixture is introduced at a normal operating pressure of 30 lb./sq.in. obtained by use of a Jameson positively-located vane-type supercharger running at crankshaft speed and producing positive pressure from 300 r.p.m. upward.

Previous engine produced 138 hp./liter on the brake at 4500 r.p.m. and an eight- or sixteen-cylinder horizontally-opposed engine of the same type is planned. Capacity of four-cylinder engine 1½ liters. Bore 77 mm. Stroke 90 mm. *Flight*, August 10, 1939, page 144, 2 illus.

Double Propeller Drive with Propeller a Distance from the Engine on Remote Drive. Aircraft power plants with two adjacently located propellers turning in opposite directions at a distance from the engine are being manufactured by the French National Engine Manufacturing Company. Remote drive comprises a shaft carrying a spur pinion at each end, these pinions having splined joints with the shaft. Torsional vibration damper consists of a tube rigidly secured to the shaft at its forward end and connected to it at its rear end through friction discs. Gear drive permits a torsional deflection of 1 deg. 20 min.

Transmission gear shaft drives a primary shaft fitted with a 21-tooth, wide-faced pinion and driving two concentric secondary shafts, each provided with an 18-tooth pinion. Reduction gear proper weighs 195 lb., two propeller hubs, 186 lb., and whole assembly 465 lb. (for an engine developing 1200 hp. at take-off and 900 hp. at 2700 r.p.m. at 13,000 ft.). *Automotive Industries*, September 15, 1939, page 279, 2 illus.

Unusual Engines. The two-cycle four-cylinder vertical inline engine developed by an Englishman, M. Jameson, has distribution by slide valves and high intake pressure. A volumetric compressor with vanes turning at crankshaft speed gives an intake pressure of 2 kg. Bore 72 mm. Stroke 90 mm. Cylinder displacement 1.500 liters.

Engine designed by an American, S. W. Neighbours, develops 500 hp. at 4500 r.p.m. and has only thirty parts in motion, the connecting rods, pistons and cylinders being eliminated. Rotating motor has a diameter of 66 cm. and length of 45 cm. Weight is 188 kg. Fuel consumption is said to be 30 liters/hr. Details of these two engines are given. *Les Ailes*, August 24, 1939, page 8, 2 illus.

The B.M.W. 132-L Aircraft Engine. B.M.W. 132-L 9-cylinder radial engine without reduction gear was used on the Focke-Wulf Condor in its record flights to New York and Tokyo. New features of the engine include: an improved cylinder design with increased and extended cooling ribs; stronger two-piece crankshaft with compressed cone connections; a new design of mounting for auxiliary apparatus with a horizontally-flanged magneto, current generator, air compressor and starter; and a tachometer connection for remote control, or driveshafts for direct tachometer drive. Bore 155.5 mm. Stroke 162.0 mm. Total capacity 27.7 liters. Power output 800 hp. at 2230 r.p.m. for 1 min. at 1.0 km., and 760 hp. at 2150 r.p.m. for 5 min. at 1.4 km. Weight without accessories 460 kg. Fuel consumption at cruising 242 g./hp.-hr., and oil 2–4 kg./hp.-hr. Few details characteristics and performance curve. *Luftwissen*, June, 1939, page 209, 2 illus., 1 table.

Technical Notes. Alfa Romeo 135 R.C. 32 18-cylinder double-row radial engine of 48.2 liters cylinder displacement has a volumetric ratio of 6.6:1 and an intake pressure of 830 mm. of mercury. It develops 1250 hp. at 2400 r.p.m. at ground level, 1400 hp. at 3400 meters, and 1500 hp. with 960 mm. of pressure for take-off. Weight 950 kg. Diameter 1.315 meters. Fuel consumption at normal power 265 gr. at ground level and 250 gr. at 3400 meters. Short description. *Les Ailes*, August 24, 1939, page 8, 1 illus.

On an Armstrong-Siddeley Jaguar 14-cylinder two-row radial engine, atomized water has been injected between carburetor and supercharger to improve the antidetonating characteristics of the fuel. It is said that, with a ratio of 80 percent of water to combustible (?), an appreciable reduction in temperature, a decrease in fuel consumption, and an increase in power have been obtained. Brief reference. *Les Ailes*, August 31, 1939, page 7.

Parts and Accessories

Double or Single Fuel Supply Systems? Use of two pumps to supply fuel to aircraft-engine cylinders is considered, each pump being controlled mechanically and separately, and each being capable of assuring the correct supply to the engine. Problems involved when fuel supply depends on only one suction pipe and only one pump are discussed in detail. Experience gained in accidents to fuel-supply systems, the supply of fuel to engines, and various installations of fuel-supply systems are described. Illustrations include: fuel supply installations on the Armstrong-Siddeley Tiger VIII, De Havilland, Junkers Jumo 211, Argus and Hirth engines; the "Graetzin-pumpe" double pump having a diaphragm and two independent suction pipes and mounted on the Mercedes-Benz D.B.600; and a "Maihak" M.F.P. double pump mounted on a Bramo 323 engine. *L'Aéronautique*, July, 1939, pages 280–285, 14 illus., 1 table.

Aircraft Fire-Fighting Equipment. Graviner automatic device described was designed to prevent, or to put out, fire in the engine compartment of aircraft in event of a crash or fire occurring during flight. The equipment is now being standardized for Royal Air Force aircraft, and Graviner pipes for distribution of methyl bromide fire-extinguishing fluid now form an integral part of the Rolls-Royce, Bristol, Napier and Armstrong-Siddeley aircraft engines being built for the R.A.F.

General application of the Graviner system, effect of methyl bromide as a fire-fighting reagent, and the automatic switches are described in detail. Drawings show the wiring diagram for a twin-engine aircraft with two extinguishers, arrangement of piping around the engine, bottle and bracket, temperature switch, and the inertia and gravity switches. Experiments with a Bristol Pegasus engine at the Royal Aircraft Establishment are also described. *Engineer*, August 25, 1939, pages 217–219, 12 illus. *Aeroplane*, September 7, 1939, page 318.

Carburetor Fire Screen. Carburetor fire screen developed by Aviation Service Corporation for preventing fires resulting from back-firing in aircraft engines. Device consists of a copper screen using a gage and screen identical to that utilized in the Davy Mine Safety Lamp. Flight tests show a relatively small power loss due to its use. Screen is located in a horizontal plane at the throat of the carburetor inside the carburetor air-heater box. Few details. *Aero Digest*, September, 1939, page 155.

Turbines

Tests on a New Internal Combustion Turbine. G. Jendrassik. New internal-combustion turbine designed by the author develops 100 hp. at 16,400 r.p.m. In tests conducted by the Hungarian Institute of Technology and Materials Testing, the turbine efficiency obtained was 21.2 percent (relation between effective brake output and lower heating value of the gasoil used as fuel). Turbine design is described and test results are given in a table. Test installation and design of blades of the turbine and compressor are shown in photographs. *V.D.I.*, July 1, 1939, pages 792–793, 3 illus., 1 table.

Meteorology

On the Theory of the Ceiling Projector. W. E. K. Middleton. Elementary geometry of the measurement of cloud heights at night by means of the ceiling projector. Expressions are developed for the apparent brightness of the spot of light under various atmospheric conditions, and for the total flux density from the spot at the observing station. Visibility of the spot is also discussed. *Optical Soc. Am., Jour.*, August, 1939, pages 340–349, 9 illus., 5 tables, 26 equations.

The Readjustment of Certain Unstable Atmospheric Systems Under Conservation of Vorticity. V. P. Starr. It is supposed that in the initial state, two masses of fluid of differing densities lie side by side, at rest relative to the earth, separated by a vertical plane. Assuming no mixing of the fluids, solutions are given for the following problems: what will be the shape of the free surface and of the internal boundary, if the system is allowed to come infinitely slowly to equilibrium (taking into consideration the effect of the earth's rotation on all motions involved in readjustment); and what will be the distribution of velocities generated by action of pressure gradients and of Coriolis forces within each mass of fluid. *Monthly Weather Rev.*, May, 1939, pages 125–134, 5 illus., 103 equations.

Experimental Studies of Anemometers. S. P. Fergusson. Notes concerning the use of records from 3-cup and 4-cup anemometers. *Am. Meteorological Soc., Bul.*, September, 1939, pages 307–309.

Extracts from Notes Derived from Synoptic Maps and Flights in the Manila-Guam Sector. L. Harmantas, Pan American Airways. Conclusions reached in a synoptic analysis of typhoon formation for over three years, supplemented with weather reports from airplanes in flight and temperature soundings. For typhoon development a displacement of a low-pressure field and the necessary trajectories of air streams are required. Once the proper trajectories are obtained, the low-level convergence (Stcu levels) and the upper level divergence (Ci or perhaps even Ast levels) follow. Circulation then sets in and an increase in gradient or a more northward displacement will result in intensification in accordance with the law of conservation of angular momentum. *Am. Meteorological Soc., Bul.*, September, 1939, pages 301–303.

The Filling of the New England Hurricane of September, 1938. R. Wexler. Quantitative determination of the amount of added friction over land areas, which would be necessary to fill the hurricane at the observed rate. *Am. Meteorological Soc., Bul.*, September, 1939, pages 277–281, 2 illus., 4 tables, equations.

Pressure and Temperature Variations in the Free Atmosphere and Their Effect on the Life History of Cyclones. B. Haurwitz. Investigations over Europe proved that at greater heights the maxima and minima of pressure occur later than at the earth's surface while temperature extremes take place earlier at greater heights. Corresponding relations over this continent are expected to differ at least in certain respects since a previous study had shown that by comparison with the upper layers the variations of temperature and pressure in the lowest atmospheric layers are stronger over North America than over Europe. Results of radio soundings taken at Boston to determine these relations between the upper and lower atmosphere are discussed. *Am. Meteorological Soc., Bul.*, September, 1939, pages 282–287, 3 tables.

Some Characteristics of Philippine Typhoons. C. E. Deppermann. Data on interesting phases of typhoon behavior are given, and certain incorrect statements which appear in standard meteorological textbooks are modified. Results of study of practically all typhoon records of the observatory from its foundation in 1865 until the present. *Am. Meteorological Soc., Bul.*, September, 1939, pages 303–307, 1 illus.

Vertical Structure of the Atmosphere in Autumn Between the Azores and the Bermudas. P. Durandin, V. Mironovitch, and A. Viaut. Study of upper-air conditions in the fall of 1937 as revealed by 48 radiosondes (Bureau) most of which reached well into the stratosphere (16–18 km.), and by 204 pilot-balloon ascents and 6575 surface reports from ships, all collected by the Carimaré between August 17 and November 13. Long abstract from Report No. 29 of French Meteorological Office, 1938. *Am. Meteorological Soc., Bul.*, September, 1939, pages 315–318, 2 illus.

Aircraft Radio

Built-In Equipment. Special Marconi transmitters and receivers for the De Havilland Flamingo transport airplane include full direction-finding and homing facilities as well as a separate blind-approach receiver for use with normal V.H.F. beacons. Special feature of the normal transmitter is that it can be used for "listening through" during both telegraphic and telephonic transmissions, while there is a "side-tone" circuit which permits the operator to hear his own messages. Wave range covers stages from 15–22 to 550–1100 meters. One of the two receivers covers four similar series of bands with a "spot" wave length of 183 meters. It is used for communication purposes but is also tuned to a direction-finding circuit. Second receiver is a combined communication and D/F set covering wave lengths between 150 and 2000 meters, and can be used as a fixed-aerial homing system or by rotation of the loop, for obtaining bearings from different stations. Discussion. *Flight*, September 14, 1939, page 242h, 2 illus.

New Radio Apparatus for Gliders. The large wide-range radio apparatus described was installed on the gliders used in the German-Italian soaring expedition to Libya which was undertaken for the purpose of studying vertical air movements over terrain of geological uniformity exposed to strong waves of the sun.

Requirements included: unconditional reliability in operation; telephony for shorter distances (at least 20 km.) and for coupled flight, and telegraphy for greater distances; a reliable minimum range of 100 km. in flight and 25 km. in case of landed aircraft; easy operation by the pilot; apparatus that should be dustproof, and weighing, including current sources, not more than 12 kg. at the most; and apparatus which could be used in four types of gliders.

The research described was carried on by a Stuttgart research group for the D.V.L. to develop equipment to meet these requirements. A 75-mm

wave was selected. A transmitter having a varioquartz controlled oscillator, and a three-stage straight receiver were developed. External dimensions were 17 × 17 × 22 cm. Anode battery and accumulator could be installed in any place in the fuselage. Apparatus weighed 4.5 kg. while the accessory batteries, head receiver, and antenna weighed 5.6 kg. *Luftwissen*, June, 1939, pages 207–209, 5 illus.

U- and H-Adcock Radio Direction Finders for Air Transport. O. Heer. Nature of these types of radio direction finders, which are named U and H installations according to the form of antenna used on the ground, are discussed in detail. *V. D.I.*, July 29, 1939, pages 878–880, 8 illus.

Aeronautical Radio Apparatus, Accessories, Materials. Directory of aero radio apparatus, accessories, parts, materials, and manufacturers. Tabulated illustrated descriptions are given for more than 100 ground and aircraft radio apparatus, and for representative accessories, parts, and components. *Aero Digest*, September, 1939, pages 69–108 and 143–151 (alternate pages).

Aircraft Radio—The State of the Industry. H. W. Roberts. Analysis of the past, present, and future aspects of aircraft radio. *Aero Digest*, September, 1939, pages 44–47, 164, 9 illus.

Aviation Radio. D. Fink. First issue—Air Radio and Instrument's AR-AUX beacon receiver having a clip-on battery compartment, and Aerovoice send-receive radio equipment for aircraft weighing 18 lb. and having an 8-watt, carrier output. Brief descriptions of these devices, and short review of "Aeronautic Radio," a new manual for operators and pilots by Lt. M. S. Eddy.

Second issue—Airtrack marker beacon transmitter mounted on a motor tricycle and including complete power supply, RCA AVR-15 beacon receiver, and Carter genemotor heavy-duty power supply for aircraft use. Brief descriptions. *Aviation*, August and September, 1939, pages 44 and 44, 46, 5 illus.

The Calibration of Four-Aerial Adcock Direction-Finders. W. Ross. Method by which it is possible to determine the minimum radius at which a four-aerial Adcock direction finder may be calibrated for instrumental error without introducing spurious effects due to proximity of the calibrating transmitter to the direction finder. This minimum radius is shown to depend upon spacing of aerials, wave length, and inherent accuracy of the direction finder to be calibrated. In most cases the minimum radius is found to be between 0.6λ and 3.5λ. Such distances, while usually easily attainable on the short-wave band, may not be possible in the case of medium or long wave lengths.

Discussion covers: errors due to proximity of calibrating transmitter; modification of existing instrumental errors by proximity of the calibrating oscillator (phase unbalance, amplitude unbalance between two members of any pair of aerials, and phase or amplitude differences of one pair of aerials relative to the other pair); combination of results for the three terms in the general expression for field strength; practical application of results; result of experimental work; and effects of ground attenuation. Communication from the National Physical Laboratory. *Instn. Electrical Engrs., Jour.*, August, 1939, pages 192–203, 8 illus., many equations.

The CAA and Aircraft Radio. C. I. Stanton. General considerations which have governed the policy of the Civil Aeronautics Authority in dealing with aircraft radio and its regulation are considered, and reference is made to systems to be installed at airports for testing. *Aero Digest*, September, 1939, pages 59, 164.

Procedure Problems in Engineering Aircraft Radio. D. S. Little. Procedure in developing aircraft radio apparatus, and purpose of the C.A.A. type certification tests. *Aero Digest*, September, 1939, page 50–51.

Radio in Aviation: A General Survey, with Special Reference to the Royal Air Force. N. F. S. Hecht, British Air Ministry. Conditions of radio communication peculiar to aircraft operation, both radiotelegraphy and radiotelephony, in regard to aerials, earths, bonding, power supply, range of communications, weight, bulk, vibration, noise, temperature, atmospheric pressure, voltage stability, intercommunication, listening-through, accessibility and remote control, fire risk, electric shock, monitoring, fatigue, lightning, and rain and dust static. Peculiar features of direction finding under aircraft conditions in regard to loops, icing up, and polarization error, as well as special features of ground direction finding connected with transmissions from aircraft, including airplane effect and rotary, track, and blind-approach beacons. Discussions of paper are included. *Instn. Electrical Engrs., Jour.*, August, 1939, pages 215–241, 12 illus.

Research in Aviation Radio. F. C. McMullen. Development of radio research in the United States, and references to present research being undertaken. *Aero Digest*, September, 1939, pages 48–49, 168.

Symposium on Radio Direction-Finding. R. L. Smith-Rose. Introduction to six papers which describe results of investigations in radio direction finding carried out by the Radio Department of the National Physical Laboratory during the past few years. Discussions before the Wireless Section of the Institution, and Dr. Smith-Rose's reply on behalf of the authors are also given. "An Improved Medium-Wave Adcock Direction-Finder," R. H. Barfield and R. A. Fereday. "A Short-Wave Adcock Direction-Finder," R. H. Barfield and W. Ross. "Radio Direction-Finding on Wave Lengths between 6 and 10 Meters (Frequencies 50 to 30 Mc./sec.)," R. L. Smith-Rose and H. G. Hopkins. "The Measurement of the Lateral Deviation of Radio Waves by Means of a Spaced-Loop Direction-Finder," R. H. Barfield and W. Ross. "A Sense-Finding Device for Use with Spaced-Aerial Direction-Finders," R. A. Fereday. "The Calibration of Four-Aerial Adcock Direction-Finders," W. Ross. *Instn. Electrical Engrs., Jour.*, August, 1939, pages 203–214.

Aeronautical Personnel

Dealing with the Problem of Personnel. C. S. Mattoon. Task of training inexperienced men falls on the aviation trade schools, both public and private. These institutions have specialized extensively on a training program applicable primarily to the repair and maintenance of aircraft and aircraft engines, but must now meet a more comprehensive program which encompasses instruction as useful to the manufacturer's organization as to the airlines. Properly organized courses acceptable to manufacturing organizations are discussed. Distribution of time devoted to various aircraft and related subjects in the Burgard Vocational High School is outlined in a table. *Aero Digest*, September, 1939, pages 36–37, 3 illus.

Book Reviews

Physikalische und Chemische Vorgänge bei der Verbrennung im Motor; Schriften der Deutschen Akademie der Luftfahrtforschung, Heft 9; R. Oldenbourg, München, 1939; 412 pages, R.M. 30.

This publication includes the proceedings of the fifth open meeting of the German Academy of Aeronautical Research on May 10 and 11, 1939, along with biographical sketches of the authors of the papers.

The articles included are: On the Chemical Constitution of Fuels and Oils (Bütefisch); Adaptation of Engines to the Fuel Used and the Ways of Realization in Germany (Pier); New Advances in Synthetic Fuels for Aircraft (Natta); Fundamentals of the Mechanism of Decomposition of Hydro-Carbons (Eucken); Raman Spectra of Several Paraffines (Bonino); The Physico-Chemical Processes of Combustion in Engines (Jost); On the Mechanism of Hydro-Carbon Oxidation during the Reaction $HCO + O_2 = CO + HO_2$ (Lewis and von Elbe); Detonation and Hydro-Carbon Combustion (Egerton); Considerations on the Detonation Process in Otto-Engines (Broeze, van Driel, and Peletier); On Detonation and the Accompanying Decrease in the Efficiency of the Otto-Engine (E. Schmidt); Mutual Influence of Mixture and Ignition Processes in the Combustion Chamber (F. A. F. Schmidt); New Investigations on the Origin and Time of Combustion in Diesel Engines (Nägel); Advances in the Study of Combustion in Diesel Engines (Neumann); The Evaluation of Fuels on the Basis of Their Ignition and Burning Characteristics (Lindner); Fuel Requirements from the Standpoint of the Engine Designer (Neugebauer). Discussions are printed after each of the articles.

The Ships and Aircraft of the U. S. Fleet, compiled by JAMES C. FAHEY; The Herald-Nathan Press, Inc., New York, 1939; 47 pages.

This booklet condenses in its few pages a statistical and pictorial review of the U.S. Navy and its air arm. It should serve as a handy reference book for those who wish to secure information about the types and characteristics of our naval war- and aircraft. The descriptions of the airplanes used by the Navy give all of the information usually required. Even though the author states that the data are compiled from non-confidential sources his position as Associate of the U.S. Naval Institute gives the information an authoritative character.

Air-War, by W. O'D. PIERCE; Modern Age Books, Inc., New York, 1939; 224 pages, $0.50.

The ambitious title of this book is qualified by the sub-title, "Its Psychological, Technical and Social Implications." A previous volume published in 1937 dealt with the technical and social aspects.

Mr. Pierce uses four biographies as case histories. He studies the work of Oswald Boelche, the famous German Ace, F. I. (Tex) Lord, the American Ace, A. H. G. Fokker, the Dutch aircraft builder, and the experiences of an unnamed English pilot. He tries to analyze their motives and reactions as indicative of those of the average man under the strain of aerial warfare.

After a sketchy account of the history of aviation the author shows what aerial war must mean and indicates some of the forces which have created the present situation.